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VOLUME 31 SEPTEMBER, 1957 NUMBER 5

TERTIARY ECHINOIDEA FROM BRITISH SOMALILAND

PORTER M. KIER
U. S. National Museum

ABSTRACT—Thirty-eight species of fossil echinoids are described from the Tertiary of British Somaliland; eight from the Paleocene, twenty-eight from the Eocene, one from the Miocene, and one from a raised beach. The following species are new: *Pedinopsis? melo Opissaster auraduensis, Schizaster (Paraster) hunti, S. (Paraster) duroensis, S. (Paraster) karkarensis, Plesiolampas curriae, P. auraduensis, Ambipleurus rotundatus, Brightonia macfadyeni,* and *Arcaechinus auraduensis.* Three new genera are described: *Brightonia, Leviechinus,* and *Arcaechinus.* Evolutionary and growth studies are included of *Echinolampas fraasi* de Loriol, and *Echinocyamus polymorpha* (Duncan and Sladen); and two abnormal specimens of *Linthia somaliensis* Currie, and one of *Migliorinia migiurtina* Checchia-Rispoli are discussed. The echinoids from the Lower Auradu Series indicate that that series is Paleocene and not Lower Eocene as formerly supposed.

PREVIOUS WORK

GREGORY (1900, p. 42) and Newton (1905, p. 173) reported several Tertiary echinoids from Somaliland, but their specimens were too poorly preserved for specific identification. Currie (1925) described three species from the Auradu series, and later (1927) four more species from the Auradu and Karkar series. Finally, Currie (1943) described five species from Somaliland from collections in the American Museum of Natural History. Only two of these species were well-enough preserved for specific identification.

Checchia-Rispoli, in a series of papers (1941, 1942, 1944, and 1950) described seventeen echinoid species from the Karkar series of Italian Somaliland. Most of the species reported by both Currie and Checchia-Rispoli, are represented in the Sedgwick Museum Collection.

SYSTEMATIC CLASSIFICATION

Mortensen's classification has been used throughout this paper. Where the author has disagreed with his system, the differences are discussed. His monographs have been of great assistance.

LOCALITIES

The locality numbers are those of Macfadyen (1933, p. 49–62) and their geographical co-ordinates, and often position in stratigraphical sections, can be found in his book.

ACKNOWLEDGMENTS

It gives me great pleasure to acknowledge the help of Mr. A. G. Brighton, who had provisionally worked on the collection, and who supervised my research throughout three years at Cambridge.

I want to thank W. A. Macfadyen and

Barrington Brown who collected the echinoids and presented them to the Sedgwick Museum. Macfadyen's material was particularly useful because he had carefully recorded the position of his localities and had, wherever possible, indicated their occurrence on stratigraphical sections. I also want to acknowledge several very informative conversations I have had with him.

I would like to thank both R. V. Melville and Professor H. L. Hawkins for their opinions on a tetramerous variant in the collection, and the late Th. Mortensen for his opinions on the great numbers of *Echinocyamus polymorpha*. I am indebted to Mr. L. Bairstow for making available many echinoids from the collections in the British Museum of Natural History.

Finally I want to thank Professor King for permitting me to study at Cambridge, and for the use of the ample and generous facilities of the Sedgwick Museum.

The manuscript was typed by Mrs. Lou Barrett at the University of Houston.

PART I

STRATIGRAPHY AND THE ECHINOID FAUNAS

The Lower Tertiary formations of British Somaliland have been described mainly by Wyllie (1925), Barrington Brown (1931), and Macfadyen (1933, 1952). The formations with their approximate maximum thicknesses in feet are listed below:

Middle Eocene	Karkar series	800′
	Anhydrite series	1000′
Lower Eocene Paleocene	Upper Auradu series Lower Auradu series	1200′

Lower Auradu series.—The lower part of the Auradu series, or of the Allahkajid where the Auradu is missing, may be Paleocene. The formation consists either of a series of limestones and shales, or a massive limestone. From these beds have been collected the eight species listed below:

Brightonia macfadyeni, n. sp.
Leviechinus gregoryi (Currie)
Opissaster somaliensis Currie
Opissaster auraduensis, n. sp.
Schizaster (*Paraster*) *hunti*, n. sp.
Schizaster (*Paraster*) *duroensis*, n. sp.
Plesiolampas curriae n. sp.
Plesiolampas auraduensis, n. sp.

All of these species are restricted to these lower beds and none of them have been reported outside of British Somaliland. The fauna shows affinities with both the Cretaceous and Eocene, and its position seems intermediate between the two.

Two of the species are allied with Cretaceous species. *Brightonia macfadyeni* is the type species of a new genus of the family Stenonasteriade. This family has hitherto been considered to be restricted to the Cretaceous. *B. macfadyeni* somewhat resembles *Iraniaster morgani* Cotteau & Gauthier from the Senonian of Iran. The other type species of a new genus, *Leviechinus gregoryi* (Currie), closely resembles *Somaliaster magniventer* Hawkins from the Cretaceous of British Somaliland.

Opissaster auraduensis resembles a Lower Eocene form, *Hemiaster schweinfurthi* de Loriol from Egypt, and *Opissaster somaliensis* Currie is very similar to *Opissaster digonus* (D'Archiac) from the Middle Eocene of India. *Schizaster hunti* seems quite unrelated to any other species from the Eocene or Cretaceous.

Of all the species from these beds, the two species of *Plesiolampas* most closely resemble ones previously described. *P. auraduensis* is very similar to *P. elongata* Duncan & Sladen from the Paleocene of India. *P. curriae* is almost identical with the Paleocene species *P. ovalis* Duncan & Sladen from the Ranikot beds of India. The resemblance is so close that Currie referred her Somaliland specimens to *P. ovalis* and stated that the lower part of the Auradu series, from whence her specimens came, was probably equivalent to the Ranikot beds.

This resemblance of *P. curriae* and *P. auraduensis* to Paleocene forms, and the affinities of some of the other species to both Cretaceous and Eocene species indicates a Paleocene age for these lower beds of the Auradu series.

While the Somaliland echinoids from the higher horizons of the Auradu series and from the Karkar series have a close affinity with the Egyptian forms, there is no resemblance between these Lower Auradu species and the Egyptian ones. This may be evidence that the Lower Libyan series is not Paleocene. Cuvillier (1930, p. 31) may have

TABLE 1.—LIST OF THE SPECIES SHOWING THEIR STRATIGRAPHIC DISTRIBUTION IN BRITISH SOMALILAND*

Species	Paleocene	Eocene		
		Lower	Middle	
	Lower Auradu series	Upper Auradu series	Anhydrite series	Karkar series
Rhabdocidaris sp. cf. *R. zitteli* de Loriol	—	×	—	—
Porocidaris schmidelii (Münster)	—	—	—	×
Pedinopsis ? melo, n. sp.	—	×	—	—
Porosoma lamberti Checchia-Rispoli	—	—	—	×
Ambipleurus rotundatus, n. sp.	—	×	—	—
A. douvillei (Lambert)	—	×	—	—
Echinolampas fraasi de Loriol	—	—	—	×
Plesiolampas curriae, n. sp.	×	—	—	—
P. auraduensis, n. sp.	×	—	—	—
Conoclypus delanouei de Loriol	—	×	—	—
Echinocyamus polymorpha (Duncan & Sladen)	—	—	×	×
Brightonia macfadyeni, n. sp.	×	—	—	—
Leviechinus gregoryi (Currie)	×	—	—	—
Pharaonaster sp. cf. *P. ammon* (Desor)	—	×	—	—
Opissaster farquharsoni Currie	—	×	—	—
O. auraduensis, n. sp.	×	—	—	—
O. somaliensis Currie	×	—	—	—
O. derasmoi Checchia-Rispoli	—	—	—	×
O. darasmoi var. *angulatus*, n. var.	—	—	—	×
Hemiaster (*Trachyaster*) sp.	—	×	—	—
Schizaster africanus de Loriol	—	—	—	×
S. (*Paraster*) *hunti*, n. sp.	×	—	—	—
S. (*Paraster*) sp. cf. *S.* (*P.*) *meslei* Peron & Gauthier	—	—	—	×
S. (*Paraster*) *karkarensis*, n. sp.	—	—	—	×
S. (*Paraster*) *beloutchistanensis* (D'Archiac)	—	—	—	×
S. (*Paraster*) *duroensis*, n. sp.	×	—	—	—
Linthia somaliensis Currie	—	×	—	×
L. cavernosa de Loriol	—	—	—	×
Lutetiaster maccagnoi Checchia-Rispoli	—	—	—	×
Arcaechinus auraduensis, n. sp.	—	×	—	—
Migliorinia migiurtina Checchia-Rispoli	—	—	—	×
Eupatagus cairensis de Loriol	—	—	—	×
E. dainellii (Checchia-Rispoli)	—	—	—	×
E. fecundus (Checchia-Rispoli)	—	—	—	×
E. sp. cf. *E. cordiformis* Duncan & Sladen	—	×?	—	—
Brissopsis sp. cf. *B. raulini* Cotteau	—	—	—	×

* *Fibularia dubarensis* occurs in the Miocene Dubar series, and *Heterocentrotus mammillatus* was collected from a raised beach.

been correct when he stated that the Paleocene was only deposited in a small area in Egypt and that the Lower Libyan series was not Paleocene but Lower Eocene.

With the information available, it is not possible to separate these Paleocene beds from the higher beds of the Auradu series, which are clearly Lower Eocene. Wyllie (1925, p. 9) divided the Auradu series into two divisions, a basal massive limestone and an upper thin-bedded chalky limestone. Macfadyen (1933, p. 23) called this lower massive bed the Auradu Limestone and the upper bed the Allahkajid Beds. Macfadyen notes that it is impossible to draw a clearly defined boundary between the two and states that it is possible that one may be, to some extent, a facies of the other. I have not been able to find the relation of this Paleocene fauna to these divisions.

The nine species were collected at Wataragaura (Macfadyen 1933, Strata Section

III), Biyo Goro (Section I), Kalareri (Section XXIV), Allahkajid (Section IV), and at Duro Hills. At Wataragaura, *Opissaster somaliensis* and *Plesiolampas curriae* occur at the base of the series just above the Cretaceous Nubian Sandstone. Macfadyen does not indicate whether or not this is the Auradu Limestone or the Allahkajid beds. *Schizaster hunti* occurs at Biyo Goro, low in the series in the Allahkajid beds. At Kalareri, *Opissaster somaliensis* occurs midway in the section, but the position of this section relative to the bottom of the Auradu series is not known. All of the species except *Plesiolampas auraduensis* occur at Allahkajid in the Allahkajid beds just above the Nubian Sandstone. According to Wyllie and Macfadyen no Auradu Limestone occurs here. It is possible that there is an unconformity at the top of the Nubian Sandstone and that the Auradu Limestone was removed, but it seems more probable that the Auradu Limestone is, as Macfadyen has suggested, just a facies of the Allahkajid beds. With the evidence at hand, it is only possible to say that the beds occurring at the bottom of the Auradu series are Paleocene. Probably a careful study of the lamellibranchs would make it possible to determine the upper limits of these Paleocene beds.

Upper Auradu series.—The echinoids collected from the limestones and shales of the upper part of the Auradu series are, with little doubt, Lower Eocene. The following eleven species were collected from these beds:

Pharaonaster sp. cf. *P. ammon* (Desor)
Opissaster farquharsoni Currie
Trachyaster sp.
Linthia somaliensis Currie
Conoclypus delanouei de Loriol
Arcaechinus auraduensis, n. sp.
Ambipleurus rotundatus, n. sp.
Ambipleurus douvillei (Lambert)
Rhabdocidaris sp. cf. *R. zitteli* de Loriol
Pedinopsis? melo n. sp.
Eupatagus sp. cf. *E. cordiformis* Duncan & Sladen

All of these species with the exception of *Linthia somaliensis*, are restricted to the Upper Auradu series. *L. somaliensis* occurs, in very limited numbers, in the Middle Eocene Karkar series.

There seems little question that these echinoids are Lower Eocene. *Conoclypus delanouei*, *Pharaonaster ammon*, and *Rhabdocidaris zitteli* all occur in the Lower Eocene Lower Libyan series of Egypt. *Ambipleurus douvillei* is an exception as it has been previously reported from both the Middle and Upper Eocene of Egypt. *Linthia somaliensis* resembles very closely *L. cavernosa* from both the Lower and Middle Eocene of Egypt. *Eupatagus cordiformis* is from the Middle Eocene of India. The other species do not closely resemble any previously described species and are of little use in correlation. In general, this fauna has its strongest affinities with the Lower Eocene, although several of the species are related to Middle Eocene forms.

The evidence from other invertebrates described from these beds is less conclusive except for the Foraminifera. Considering the lamellibranchs, Newton (1905, p. 169) reported two species of *Spondylus*, *S. aegyptiacus* and *S. somaliensis* from the Tertiary of Somaliland. Macfadyen (1933, p. 24) states that these species are from the Auradu series. *S. aegyptiacus* is also found in the Lower Eocene of Egypt but this species passes up into the Karkar series in Somaliland and is thus of little use in confirming a Lower Eocene age for the series.

Cox (1931a, p. 34) describes four species of lamellibranchs which occur both in the Auradu series and in the lower Eocene Laki series of India. However, three of these species also occur in the Middle Eocene of Egypt or India. The fourth species, although it is confined to the Auradu series, may or may not occur in the Laki series of India.

The corals are of little use in correlation. Gregory (1900) described eight species from the Auradu series but all of them are new.

The foraminiferal evidence is more conclusive. Nuttall & Brighton (1931, p. 64) reported five species of Foraminifera from the beds underlying the Karkar series. Four of these species also occur in the Lower Eocene Laki series of India and two of them are considered as reliable guide species of the Lower Eocene. The combined evidence of the Foraminifera and echinoids conclusively indicates a Lower Eocene age for the Upper Auradu series.

The Somaliland echinoids are closely related to the Egyptian fauna, having four species in common and several others with

close affinities. There seems to be little relationship between the Somaliland species and the Indian forms. The only Indian species any of these specimens resemble is *Eupatagus cordiformis*.

Anhydrite series.—Above the Auradu series occurs a series of interbedded anhydrite, gypsum, and limestone called the Anhydrite series. Macfadyen provisionally refers this series to the Middle Eocene. The only fossil found in any numbers is *Echinocyamus polymorpha* (Duncan & Sladen). As this species occurs in the Middle Eocene of India, it seems probable that these beds are Middle Eocene as supposed by Macfadyen.

Karkar series.—The Karkar series, which overlies the Anhydrite series, consists of marine limestones, marls, and shales. The echinoids from this series are both numerous and well preserved. The following eighteen species and one variety were collected.

Porosoma lamberti Checchia-Rispoli
Porocidaris schmidelii (Münster)-radioles
Schizaster (*Paraster*) *beloutchistanensis* (D'Archiac)
S. africanus de Loriol
S. (*Paraster*) sp. cf. *S.* (*P.*) *meslei* Peron and Gauthier
S. (*Paraster*) *karkarensis*, n. sp.
Linthis somaliensis Currie
L. cavernosa de Loriol
Lutetiaster maccagnoi Checchia-Rispoli
Migliorinia migiurtina Checchia-Rispoli
Opissaster derasmoi Checchia-Rispoli
O. derasmoi var. *angulatus*, n. var.
Eupatagus dainelli (Checchia-Rispoli)
E. fecundus (Checchia-Rispoli)
E. cairensis de Loriol
Echinolampas fraasi de Loriol
Echinocyamus polymorpha (Duncan & Sladen)
Brissopsis sp. cf. *B. raulini* Cotteau

With the exception of *Echinocyamus polymorpha*, which also occurs in the Anhydrite series, and *Linthia somaliensis*, which occurs in the Upper Auradu series, all the above species are restricted to the Karkar series.

Undoubtedly this fauna is Middle Eocene. *Porocidaris schmidelii*, *Schizaster africanus*, *Eupatagus cairensis*, and *Echinolampas fraasi* all occur in the Middle Eocene of Egypt. *Schizaster beloutchistanensis* and *Echinocyamus polymorpha* are found in the Middle Eocene of India. *Porosoma lamberti* resembles *P. ghizense* Gauthier. *Migliorinia migiurtina* resembles *M. moelehensis* (Fourtau), and *Schizaster karkarensis* is very similar to *S. libycus* Fourtau. All three of these species are from the Middle Eocene of Egypt. *Opissaster derasmoi* has strong affinities with *O. digonus* (D'Archiac) from the Middle Eocene Khirthar series of India. *Schizaster meslei* Peron and Gauthier, to which several of the Karkar specimens are provisionally referred, is also found in the Egyptian Middle Eocene. *Brissopsis raulini* Cotteau occurs in the Middle Eocene of France.

The Middle Eocene age of the Karkar series was also conclusively shown by a study of the Foraminifera made by Nuttall and Brighton (1931, p. 49). Many of these Foraminifera were collected at the same localities as the echinoids. Smout (1954) found in beds he considered to be Middle Eocene three of the species recorded by Nuttall and Brighton in the Karkar series. Finally, Azzaroli (1950, p. 105) found fifteen species of Foraminifera in the Karkar series of Italian Somaliland which also occur in the Middle Eocene of India.

Unfortunately, the other invertebrates cast little light on the age of the series. Haas & Miller (1952) described a large collection of nautiloids from the Karkar series. They found the fauna very distinct from the fauna of Egypt and India and of little use in correlation. Again, although Cox reported (1931a, p. 34) thirteen species of lamellibranchs that were found both in the Karkar series and the Eocene of India, most of these species are found, not only in the Middle Eocene Khirthar series of India, but also in the Lower Eocene Laki series. The evidence from the Foraminifera and echinoids is sufficient to prove that the Karkar series is Middle Eocene.

Miocene.—Only one species, *Fibularia dubarensis* n. sp. was collected from beds that can be referred to the Miocene. As this species bears no close resemblance to any other Miocene species, it is of little use in proving the age of these beds. Nuttall & Brighton (1931, p. 49) studied some Foraminifera from these beds and concluded that they were Miocene. Furthermore, Cox (1931b, p. 280) noted that an oyster, *Ostrea longifolium*, which has been found in the Lower Miocene of Kenya and Pemba, also occurs in these beds.

Raised beach.—One specimen of *Hetero-*

centrotus mammillatus was collected from a raised beach near Dubar. As this species has been reported from the Pliocene to the Recent, little can be surmised of the age of this raised beach.

PART II

SYSTEMATIC DESCRIPTIONS

Class ECHINOIDEA
Subclass REGULARIA Latreille
Order CIDAROIDEA Mortensen
Family CIDARIDAE Gray
Genus RHABDOCIDARIS Desor

Rhabdocidaris Desor 1855, Synopsis des Échinides, Fossiles, p. 39.

Type species.—*Rhabdocidaris orbignyana* (Agassiz).

Rhabdocidaris sp. cf. *R. zitteli* de Loriol
Pl. 103, fig. 1,2

Rhabdocidaris Zitteli de Loriol 1881. Palaeontographica, bd. 30, p. 8–9, pl. 1, fig. 1,2.

MATERIAL.—One specimen slightly crushed, lacking its apical system.

Description.—Test of moderate size, somewhat depressed. Interambulacra wide, approximately eight plates per column. Each plate bears one large, perforated, strongly crenulated primary tubercle in middle of plate, surrounded by large scrobicular circle of tubercles. Diameter of scrobicular circle almost equal to height of plate; area between circles occupied by granules. Ambulacra narrow, slightly sinuate with simple primary plates, with conjugate pores. At midzone approximately nine ambulacral plates for each interambulacral plate. On each ambulacral plate occur two granules in transverse row between pore-pairs and perradial suture.

Remarks.—This specimen resembles *Rhabdocidaris zitteli* from the Lower Eocene of Egypt. It differs in that its primary tubercles occur in the center of each interambulacral plate, whereas, in *R. zitteli* they occur nearer the adradial suture. This specimen has only two granules in each row on its ambulacral plates, whereas, there are three in *R. zitteli*. The test of this specimen is somewhat higher than that of the Egyptian species. Probably the specimen represents a new species, but without having more than one specimen available it is impossible to be certain of the importance of these differences.

Distribution.—Upper Auradu series (Lower Eocene) of British Somaliland.

Locality.—ϕ113 (Sedgwick Mus. Cat. No. C3151).

Genus POROCIDARIS Desor

Porocidaris Desor 1855, Synopsis des Échinides Fossiles, p. 46.

Type species.—*Cidarites schmidelii* Münster, by subsequent designation of Pomel 1883, p. 112.

POROCIDARIS SCHMIDELII (Münster)
Pl. 103, fig. 3

Cidarites Schmidelii Münster 1830. In Goldfuss, Petrefacta Germaniae, bd. 1, p. 120, pl. 40, fig. 4.
Cidaris serrata D'Archiac 1847. In Agassiz & Desor, Cat. raisonne, p. 29.
Porocidaris serrata Desor 1855. Synopsis des Échinides Fossiles, p. 47, pl. 7, fig. 23.
Porocidaris veronensis Desor 1855. Synopsis des Échinides Fossiles, p. 47, pl. 7, fig. 21.
Porocidaris Schmidelii Desor 1855. Synopsis des Échinides Fossiles, p. 47, pl. 7, fig. 22; de Loriol 1880. Mém. Soc. Physique Genève, tome 27, p. 61, pl. 1, fig. 1–15; de Loriol 1881. Palaeontographica, bd. 30, p. 9–10, pl. 1, fig. 10,11.

Material.—Thirty-nine radioles.

Description.—Radioles large; largest, though incomplete, 33 mm. long, 9 mm. wide. Shafts flattened, coarsely serrated on edges, but smooth on sides. Collars broad, spinous on upper surfaces. Lower surfaces of collars radially striated, bases crenulated.

Remarks.—These radioles are very similar to those described by de Loriol from the Middle Eocene of Egypt. The only regular echinoid yet found in the Karkar series is *Porosoma lamberti* Checchia-Rispoli. These radioles could not have come from this species as the radioles of *Porosoma* are quite different, being smaller, relatively smooth, cylindrical, and without crenulations on the collar.

Distribution.—Karkar series (Middle Eocene) of British Somaliland and Middle Eocene of Germany, Egypt.

Localities.—B. 27, ϕ131, ϕ255, ϕ188, σ192 (Sedgwick Mus. Cat. Nos. C3209–13).

Order STIRODONTA
Suborder PHYMOSOMINA Mortensen
Family PSEUDODIADEMATIDAE Pomel
Genus PEDINOPSIS Cotteau

Pedinopsis Cotteau 1863, Congrès Sci. France Mém., session 28, tome 3, p. 176.

Type species.—By monotypy, *Pedinopsis meridanensis* Cotteau.

PEDINOPSIS ? *melo*, n. sp.
Text-fig. 1a,b; Pl. 1, fig. 4,5

Diagnosis.—Species characterized by melon-like appearance due to depressed adradial sutures. Ambulacral plates diadematoid triads with biserial, transversely elongated pores. Tubercles extremely small; 10–12 on each interambulacral plate, 2 on each ambulacral plate.

Material.—One specimen C3007, largely covered with matrix and its own radioles. Ambulacra and interambulacra visible in several places at ambitus and near peristome. Apical system apparently missing.

Description.—Specimen 38.0 mm. in diameter, 22 mm. high. Test probably subconical although now somewhat flattened, making it impossible to discern its original shape. Adradial sutures depressed giving melon-like appearance to test. Ambulacral areas (text-fig. 1a) approximately one-half as wide as interambulacra; inflated at middle but depressed along adradial sutures. Ambulacral plates triads (text-fig. 1b), diadematoid with biserial pores. Plates very low, wide. Poriferous zones narrow, about one-third as wide as ambulacral columns. Pores slit-like, surrounded and separated by ridge. Usually two but sometimes three tubercles in horizontal series on each plate. Interambulacra composed of many wide, low plates which bear two horizontal rows of tubercles, about 5–6 in each row. Plates about twice width of ambulacral plates. Test covered with small, perforated, regularly distributed tubercles, crenulation uncertain. Radioles striated, long, and slender with pronounced collars.

Comparison.—This species is similar to other species of *Pedinopsis* in having biserial pore-pairs and in having small tubercles on the ambulacra and interambulacra. However, its ambulacral plates are triads, whereas, in the type species *P. meridanensis*, there are six pore-pairs in each compound ambulacral plate at the ambitus. Furthermore, the distinct depressions along the adradial suture, giving a melon-like appearance to the test, distinguish this species from the type species of *Pedinopsis*. It is also significant that no other *Pseudodiadematid* has collared radioles. Probably this species belongs to a new genus but it is inadvisable to erect one on only a fragment lacking both its peristome and apical system.

Distribution.—Upper Auradu series (Lower Eocene) of British Somaliland.

Locality.—Camp 7—A.26 (Sedgwick Mus. Cat. No. C3007).

Family PHYMOSOMATIDAE (Pomel) Meissner
Genus POROSOMA Cotteau

Porosoma Cotteau 1856. Bull. Soc. géol. France, ser. 2, tome 8, p. 648.

Type species.—*Porosoma cribrum* (L. Agassiz).

POROSOMA LAMBERTI Checchia-Rispoli
Pl. 103, fig. 6,7,8

Porosoma lamberti Checchia-Rispoli 1950. Boll. Ufficio geologico Italia, v. 70, p. 22–24, pl. 1, fig. 1.

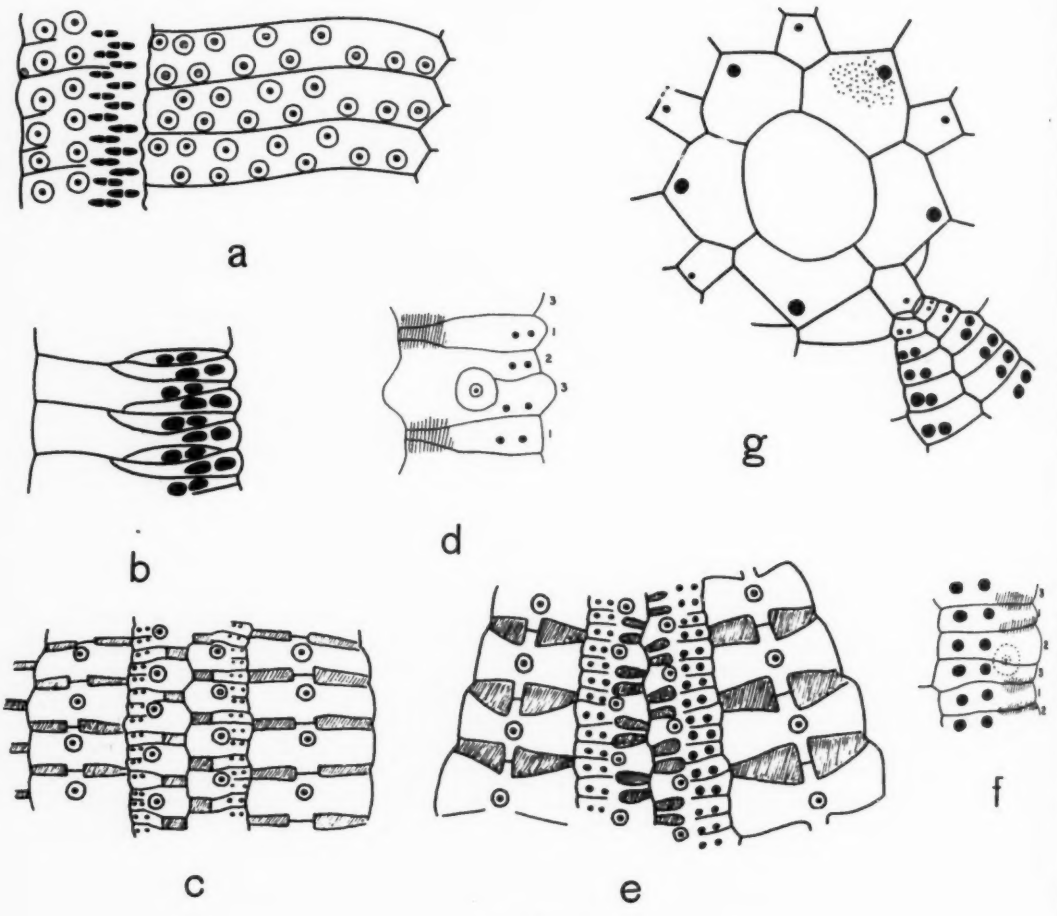
Material.—Sixteen specimens and two slabs containing many small specimens; some well preserved although apical system not preserved on any of them.

Description.—Test of moderate size, low, and hemispherical. On large specimens, marginal outline somewhat pentagonal. Ambulacra wide, with approximately 15 plates in column of a large specimen. Large primary tubercle in middle of each compound plate. Ambulacral plates polyporous with approximately six pore-pairs in each plate at midzone; poriferous zones very sinuous. Interambulacral plates wide, low, with one large primary tubercle in middle of each plate. Approximately 14 plates in column of large specimen. Peristome large, about one-third diameter of test, with distinct notches. Crenulate, imperforate tubercles occur in two regular series in each area.

Comparison.—This species resembles *Porosoma ghizense* Gauthier and *P. aegyptiacum* Gauthier from the Middle Eocene of Egypt. *P. ghizense* differs in having a row of small tubercles beside the principal series on the interambulacra. *P. aegyptiacum* differs in having more plates in the interambulacral and ambulacral columns.

Distribution.—Karkar series (Middle Eocene) of British and Italian Somaliland.

Localities.—B.11, B.15, B.27, B.51, ϕ134a, ϕ255, ϕ253, ϕ258, σ202, A.11 (Sedgwick Mus. Cat. Nos. C3152–70).



TEXT-FIG. *1*

Pedinopsis ? melo, n. sp. a. View of the plates at the midzone of the holotype, C3007, showing the slit-like, biserial pore-pairs, and the wide, low interambulacral plates with their two rows of tubercles. ×6. b. View of the weathered oral portion of an ambulacrum of the holotype showing the diadematoid triads. ×8.

Ambipleurus douvillei (Lambert). c. View of the midzone of an ambulacrum and two half-interambulacra of specimen C2978. The shaded areas are sutural depressions. ×10. d. View of a portion of an ambulacrum showing the plate sutures of a triad. The plates of the triad are numbered and the sutural depressions shaded. ×14.

Ambipleurus rotundatus, n. sp. e. View just above the midzone of an ambulacrum and two adjacent half-interambulacra of the holotype C3146. The shaded areas are the depressions at the sutures. ×10. f. View of a weathered portion of an ambulacrum of the holotype showing the plate sutures of the triads (each plate of a triad is numbered) and the location of a sutural depression (shaded). ×12. g. Apical system of the holotype, C3146, showing the exsert oculars, elongate anus, and a portion of ambulacrum I. Of interest is the newly formed plate in interambulacrum 1a. ×4.

Order CAMARODONTA Jackson
Suborder TEMNOPLEURINA Mortensen
Family GLYPHOCYPHIDAE Duncan
Genus AMBIPLEURUS Lambert

Ambipleurus Lambert 1936. Bull. Inst. égypt, tome 18, p. 42.

Type species.—By original designation, *Dictyoplerus douvillei* Lambert.

Ambipleurus rotundatus n. sp.
Text-fig. 1e–g; Pl. 103, fig. 9

Diagnosis.—Species characterized by almost spheroidal shape, and by series of double ambulacral sutural depressions.

Material.—One specimen, the holotype C3146, for the most part well preserved although part of test missing, some portions badly weathered. Apical system and part of peristome visible.

Description.—Specimen 16.6 mm. high with diameter of 19.9 mm. Test small, almost spheroidal with rounded oral and aboral surfaces. Apical system small (text-fig. 1g) with elongate anus, elevated ocular-genital ring. Largest genital pierced with madreporic pores. Oculars tilt up into ocular-genital ring; all exsert. Ambulacra narrow, with nearly straight poriferous zones, with about four porè-pairs to each interambulacral plate. Ambulacral plates triads with widest plate (number 2 in text-fig. 1f) in middle. Each triad bears one large primary tubercle on ambulacral plates 2 and 3. Deep indentations (text-fig. 1f) at both horizontal sutures of first plate of triad near perradial suture. Sutural depressions not coalesced into one pit as usual in most species of genus, but form series of alternating double depressions. Interambulacra wide, composed of approximately 17 plates in column; plates low at midzone. Primary tubercle at center of each plate, tubercles joined vertically by narrow ridge extending from apical system to peristome. Plates indented deeply at horizontal sutures giving bow-like appearance to raised portions of plates. Peristome small, with distinct notches. Single vertical series of equal-sized, perforate, crenulate tubercles occur on each ambulacral and interambulacral column.

Comparison.—This species clearly belongs in the family Glyphocyphidae. Its small test with triad ambulacral plates, nearly straight poriferous zones, and perforate, crenulate primary tubercles are features of this family. It has well-developed pits in the horizontal sutures, a feature most typical of *Ambipleurus*. It differs only in that all its oculars are exsert, whereas, in the type species of the genus and in all the other species only four of them are exsert and the fifth, ocular I, is insert. However, as only one specimen is available this character may be an anomaly peculiar to this specimen.

A. rotundatus differs from all the other species of this genus except *Ambipleurus daguini* (Jeannet 1936, p. 5) in having a series of double depressions in the horizontal sutures of the ambulacral plates, rather than having two of the sutural depressions coalesced into one as in the other species. *A. rotundatus* differs from *A. daguini* in that while both species have double depressions in the ambulacral sutures, in *A. daguini* the depressions are not double throughout their length but coalesce near the perradial suture. Furthermore, the test of *A. daguini* is more depressed with flatter oral and apical surfaces than in *A. rotundatus*.

Distribution.—Upper Auradu series (Lower Eocene) of British Somaliland.

Locality.—Ferdidin (Sedgwick Mus. Cat. No. C3146).

AMBIPLEURUS DOUVILLEI (Lambert)
Text-fig. 1c,d; Pl. 103, fig. 10

Dictyopleurus Haimai de Loriol 1884. Rec. zool. Suisse, tome 1, p. 29, pl. 34, fig. 7 (not seen). Fourtau 1898. Mém. Inst. égypt (Égypte), tome 3, p. 639,732. Fourtau 1909. Mém. Inst. égypt (Égypte), tome 6, p. 125. Fourtau 1913. Cat. Invertébrés Fossiles L'Égypt, Terrains Tertiaries, Échinides Éocènes, p. 18.
Dictyopleurus Douvillei Lambert 1932. Mém. Soc. géol. France, tome 7, p. 197–198, pl. 5, fig. 1–4.
Ambipleurus Douvillei Lambert 1936. Bull. Inst. égypt, tome 18, p. 42.

Material.—One beautifully preserved specimen showing clearly ornamentation and sutural depressions (text-fig. 1c) but lacking both apical system and peristome.

Description.—Test small, slightly depressed, ambulacra narrow, with nearly straight poriferous zones. Ambulacral plates triads; each triad bears one large primary tubercle on ambulacral plates 2 and 3 (text-fig. 1d). First plate of each triad with horizontal sutures depressed forming one coalesced pit at perradial suture. Interambu-

lacra wide, composed of two columns of wide, low plates, indented at horizontal sutures. Single vertical series of equal-sized, perforate, crenulate tubercles occur on each ambulacral and interambulacral column.

Remarks.—This specimen appears to be similar in all respects to *Ambipleurus douvillei* from the Middle and Upper Eocene of Egypt.

Distribution.—Upper Auradu series (Lower Eocene) of British Somaliland and Middle and Upper Eocene of Egypt.

Locality.—Near Camp 7-A.26 (Sedgwick Mus. Cat. No. C2978).

Suborder ECHININA Mortensen
Family ECHINOMETRIDAE Gray
Genus HETEROCENTROTUS Brandt

Heterocentrotus Brandt 1835. Prodromus animalium ab H. Mertensio in orbis terrarum circumnavigatione observatorum. Fasc. 1, (not seen).

Type species.—*Heterocentrotus mammillatus* (Linnaeus).

HETEROCENTROTUS MAMMILLATUS (Linnaeus)

For complete synonymy see Mortensen 1943, p. 409–411.

Material.—One well preserved specimen, which can undoubtedly be referred to this species.

Distribution.—According to Mortensen (1943, p. 418) this species is widely distributed over the Indo-West Pacific. As a fossil it has been recorded from the Pleistocene or Upper Pliocene of the Suez Gulf and from the Farsan Island.

Locality.—A raised beach at Dubar (Sedgwick Mus. Cat. No. C13353).

Subclass IRREGULARIA Latreille
Order CASSIDULOIDA Duncan
Suborder CASSIDULINA Delage & Herouard
Family ECHINOLAMPADIDAE Gray
Genus ECHINOLAMPAS Gray

Echinolampas Gray 1825, Ann. Philos., n.s., vol. 10, p. 429.

Type species.—*Echinanthus ovata* (Leske), by subsequent designation of Pomel 1883, p. 62

Diagnosis.—Test usually large, elongate, inflated, with smooth marginal outline. Apical system with four genital pores, madreporite very large, occupying all central part of system, with only oculars distinguishable. Ambulacra narrow, petaloid, and open. Floscelle usually well-developed, peristome usually pentagonal. Periproct elongated transversely; test covered with small tubercles.

Comparison.—*Echinolampas* is very similar to *Plesiolampas*. The main difference between the two is that in *Echinolampas* the periproct is elongated transversely, whereas, in *Plesiolampas* it is elongated longitudinally. Furthermore, in *Echinolampas* the floscelle is more developed than it is in *Plesiolampas*.

Remarks.—Lambert & Thiéry (1921–1924, p. 377–387) erected eight sections for all the many species of this genus. Unfortunately, the sections are based on variable and artificial distinctions, a fact of which they were well aware. Their object was to facilitate the task of identification, rendered difficult by the large number of species. However, although in many instances an artificial classification such as this is helpful, it is also dangerous. There is always the possibility that a worker will consider these sections as being completely distinct and fail to compare his species with closely allied species of other sections. As an example of such an error, one may quote the action of Checchia-Rispoli (1950, p. 24–29). Two species, *Echinolampas migiurtinus* and *E. migliorinii*, were referred by him to Lambert & Thiéry's section *Cylindrolampas*, and a third, *E. fraasi*, to their *Paleolampas*. From a study of similar specimens it is apparent that these species are in reality only one.

ECHINOLAMPAS FRAASI de Loriol
Text-fig. 2–5; Pl. 103, fig. 11,12; Pl. 104, fig. 1

Conoclypeus conoideus Fraas, non Agassiz, 1867. Aus dem Orient, p. 133–134. Stuttgart.

Echinolampas Fraasi P. de Loriol 1880. Mém. Soc. Physique Genève, tome 27, p. 92–93, pl. 5, fig. 1. P. de Loriol 1881. Palaeontographica, bd. 30, p. 22–23, pl. 6, fig. 1. Cotteau 1891. Paléont. Française Éocène, tome 2, p. 156. Fourtau 1898. Mém. Inst. égypt (Égypte), tome 3, p. 658. Fourtau 1900a. Bull. Inst. égypt, tome 4, ser. 1, p. 167. Lambert 1902a. Rev. critique Paléozoologie, tome 6, p. 211. Gregory 1906. Geol. Mag. D. 5, v. 5, p. 252. Lambert 1906a. Rev. critique Paléozoologie, tome 10, p.

183. Stefanini 1919. Boll. Soc. Geologica Italia, v. 38, p. 49. Lambert & Thiéry 1924. Essai Nomenclature Raisonnes des Échinides, p. 386. Checchia-Rispoli 1950. Boll. Ufficio geol. Italia, v. 70, p. 26–28, pl. 2, fig. 3,3a.

Echinolampas africanus var. *Fraasi* Fourtau 1901b. Bull. Soc. géol. France, ser. 4, tome 1, p. 623–625. Fourtau 1905. Bull. Inst. égypt, tome 5, ser. 4, p. 132. Fourtau 1913. Cat. Invertébrés Fossiles L'Égypt, Terrains Tertiaires, Échinides Éocènes, p. 31–32.

Echinolampas cf. *E. amygdala* Desor, Currie 1927. Trans. Royal Soc. Edinburgh, v. 55, pt. 2, (no. 18), p. 429–430, pl. fig. 5.

Echinolampas migiurtinus Checchia-Rispoli 1950. Boll. Ufficio geol. Italia, v. 70, p. 24–26, pl. 1, fig. 2,2a,2b.

Echinolampas (*Cylindrolampas*) *Migliorinii* Checchia-Rispoli, non Venzo, 1950. Boll. Ufficio geol. Italia, v. 70, p. 28–29, pl. 2, fig. 1,1a,1b.

Diagnosis.—Test large, varying from low, elongate to more circular, highly inflated. Petals long, almost reaching to ambitus, open. Interporiferous zones very wide; poriferous zones narrow, subequal. Periproct elongated transversely occurring below ambitus. Peristome large, pentagonal, slightly anterior of center; floscelle well-developed.

Remarks.—Fourtau (1901a, p. 623–625) examined many specimens of *Echinolampas africana* de Loriol 1880; *Echinolampas fraasi P.* de Loriol 1880, and *Echinolampas osiris* Desor 1847. He considered them to be so similar as to not warrant retaining them as separate species. He therefore made *E. fraasi* and *E. osiris* varieties of *E. africana*. Lambert (1902a, p. 211; 1906a, p. 183) pointed out that as *E. osiris* was erected 33 years before *E. africana* it could not be considered as a variety of *E. africana*. Fourtau (1909, p. 141) therefore provisionally agreed to consider *E. osiris* as a separate species. However, he continued to regard *E. fraasi* as a variety of *E. africana*. Lambert & Thiéry (1924, pl 386) separated *E. fraasi* and considered it as a separate species.

Without seeing the Egyptian specimens, it is difficult to be certain whether or not *E. fraasi* should be maintained. From de Loriol's type figures, *E. africana* and *E. fraasi* seem quite distinct. In his specimens of *E. africana*, the poriferous zones of the petals are far wider than they are in his specimens of *E. fraasi*. Furthermore, in none of the many species referred to *E. fraasi* in the Somaliland collection are the poriferous zones as wide. Therefore, it seems reasonable to retain *E. fraasi* as a separate species.

Material.—There are 170 specimens, most of them very well-preserved, which can be referred to this species previously known from the Middle Eocene of Egypt.

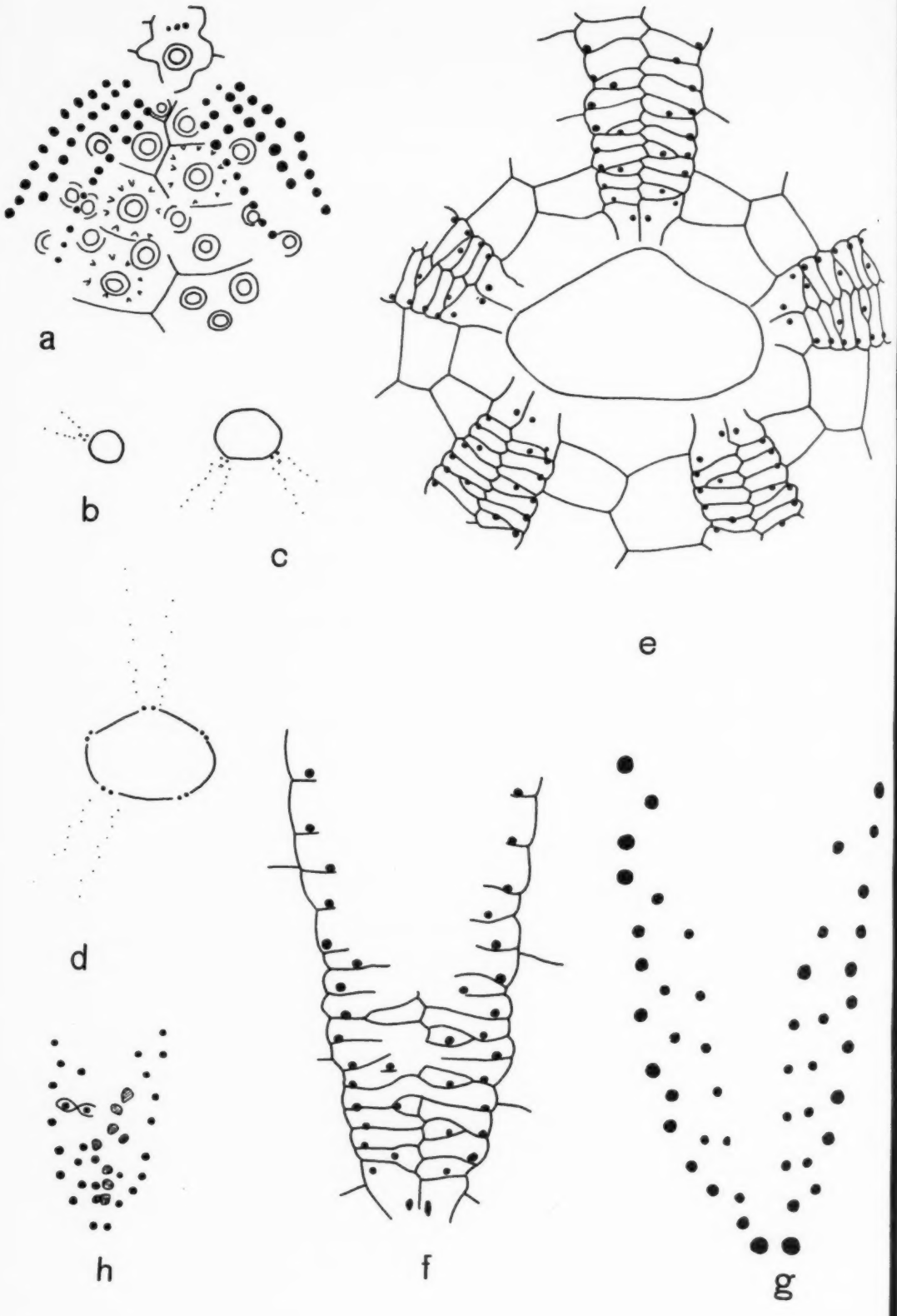
Ontogeny.—Since a large number of specimens are available, ranging in length from 4.4 mm. to 95.0 mm., it has been possible to study the growth changes of this species and to compare them with the changes in the modern *Echinolampas depressa* as described by Agassiz (1904).

Aboral surface.—In the smallest specimen, C13354, which is only 4.4 mm. long, pore-pairs are already present. In petal III there are 2–3; in petals II and IV there are 2 in IVa and IIb, and 6 in IIa and IVb. In petals V and I, there are 7–8 in Va and Ib, and 2–3 in Ia and Vb (text-fig. 2a). The pores of these pairs are joined in a conjugation groove transverse to the length of the petal. Therefore, in text-fig. 2a, while a single pore is depicted nearest the apical system in poriferous zones Va and Ia and b, it is probable that it is actually just one of a pair, the second being too minute to see.

The rest of the ambulacral plates, from the end of the petals to the peristome, are each pierced by a single pore. These pores, which are in line with the outer of the two columns of pores making up a poriferous zone, are large aborally but minute and and almost invisible orally.

The genital plates are unpierced, and there are three madreporic pores in the anterior part of the madreporite. A very large tubercle on the madreporite below these pores occurs on all the specimens less than 14 mm. long. On specimens larger than this the tubercle is missing and the space it occupied becomes pierced with madreporic pores. It is also at about this size that the first genital pores appear.

This specimen can be compared with one of approximately the same size of a recent species of this genus, *Echinolampas depressa* Gray, that has been figured by Agassiz (1904, pl. 64, fig. 5). In his specimen no pore-pairs have developed as yet, and there are no large tubercles on the madreporite. It is similar, however, in having only three


a
b
c
d
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madreporic pores, which also occur on the anterior part of the madreporite.

In *E. fraasi* new pore-pairs are added continually as the echinoid increases in size. While there is some decrease in the rate of production of new pore-pairs as the echinoid reaches maturity, production never ceases. This is clearly shown in text-fig. 3 in which the number of pore-pairs in poriferous zones IIb and IVa, and Va and Ib are plotted in relation to the length of the specimens.

As is usual in *Echinolampas*, the petals have unequal poriferous zones. In petal III poriferous zone IIIa has 0–5, with an average of 2, more pore-pairs than IIIb; poriferous zones IIa and IVb of petals II and IV are longer with 3–10, with an average of 7, more pore-pairs than IIb and IVa. Poriferous zones Va and Ib of petals V and I have from 1–8, with an average of 5, more pore-pairs than zones Vb and Ia. A. Agassiz (1883, p. 46) found a similar variation in the difference in the number of pore-pairs of the same petal in *E. depressa*. He was surprised that this difference made its appearance so early in the life of the echinoid. Perhaps he thought that the pore-pairs could have been introduced at the end of the petals. Gordon (1926a, p. 288) and many others, have shown that new tube feet are formed under the oculars. Any inequality in the number of pore-pairs in a specimen must date back to the first appearance of the pore-pairs. For example, if in a mature specimen there are six more pore-pairs in one poriferous zone than in the other of the same petal, then when the echinoid was very young, six pore-pairs must have been introduced in this longer zone before any were introduced into the other. As plates of both poriferous zones of an ambulacrum are introduced at the sate rate, this difference will remain constant throughout the growth of the echinoid.

Oral surface.—In the smallest specimen, 4.4 mm. long (text-fig. 2b), the mouth is circular with sloping sides, and the pores are still uniserial. The bourrelets are not developed. There is a deep pit behind each pair of buccal pores for the first sphaeridium. A. Agassiz (1904, pl. 64, fig. 2,3) figured the peristomal region of a specimen of approximately the same size of *E. depressa* which is similar in most respects to this specimen. Its pores are also uniserial, although they are depicted as being pore-pairs instead of single pores. As Agassiz does not mention this unusual feature, it was probably an error of the artist. One sphaeridium is also present behind the buccal pores.

In a specimen 6.9 mm. long (text-fig. 2c), the mouth had greatly changed, becoming oval transversely with nearly vertical sides. The ambulacral pores are no longer unigeminal, as a few of them are slightly displaced towards the perradial suture.

In a still larger specimen, 10.8 mm. long (text-fig. 2d), the mouth has become subpentagonal. The pores begin to show the first indication of the triserial arrangement of a phyllode with every third pore displaced towards the perradial suture. Gradually, as the echinoid grows these pores shift more towards this suture until, as illustrated in a specimen 38.0 mm. long (text-fig. 2e), they form a column four pores long. Most of the plates in which these pores occur are occluded, particularly near the peristome. In some of these plates only the pore has shifted towards the perradial suture, and the plate itself is not occluded. From this stage until the echinoid is more than twice this size there is only a slight increase in the complexity of the phyllode. In a specimen over 73 mm. long (text-fig. 2f), there are

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TEXT-FIG. 2

Echinolampas fraasi de Loriol. a. Aboral view of specimen C13354, 4.4 mm. long, showing petals V and I, interambulacrum 5, and the madreporite, which is pierced with three pores and bears a tubercle. ×21. b–g. Oral view of the peristomal region showing the growth changes in the shape of the mouth, and development of the phyllodes. The sphaeridia, where visible, are indicated by an x. ×8. b. Specimen C13354, 4.4 mm. long. c. Specimen C13355, 6.9 mm. long. d. Specimen C13356, 10.8 mm. long. e. Specimen C2778, 38.0 mm. long. f. Specimen C2624, 73 mm. long. g. Specimen C2621, 95.0 mm. long. ×8. h. Oral view of specimen C2764, 48.0 mm. long, showing sphaeridia pits in ambulacra IV. ×8.

four or five inner pores in each column, and the occluded plates have become relatively smaller and more distant from the adradial suture. However, as the echinoid approaches its maximum size, the phyllodes become very complex. In the largest specimen, 95.0 mm. long (text-fig. 2g), there are now three columns of pores. The triangular triserial arrangement, which Hawkins (1911, p. 257–265) showed to be typical of phyllodes, has been altered to a transverse linear pattern with three pores in a row.

The sphaeridia increase in number in the larger specimens. They are concentrated (text-fig. 2h) in two rows of pits along the perradial suture. As these pits are very deep and usually filled with matrix, they are easily confused with pores. Only by cleaning each one can they be differentiated.

Adult variation.—The shape of the test is very variable in this species. Some of the specimens, particularly the large ones, are very high with inflated aboral surfaces, steeply sloping sides, and flat oral surfaces, whereas, others are somewhat flattened aborally and inflated orally. In some, the greatest width is anterior to the apical system, and in others, posterior. To determine whether just one, or possibly more than one, population was represented in this group, the length, width, and height of many specimens was determined from just one locality, Tug, near Pool, Buran, and the results plotted on graphs.

The height relative to length is recorded on text-fig. 3. The great variation of the height is shown by the wide scatter of the points. The fact that there is no noticeable separation of the points into separate paths is reasonable evidence that only one population is present. Text-fig. 4-1, per cent height of length (H/L×100) to length, illustrates the tendency of the smaller and larger specimens to be higher than the others. Among all the specimens measured, the height varies from 44 to 72 per cent of the length. This difference is vividly shown in a profile drawing of two extreme specimens (diagram of text-fig. 3-2, $\frac{1}{3}$ natural size).

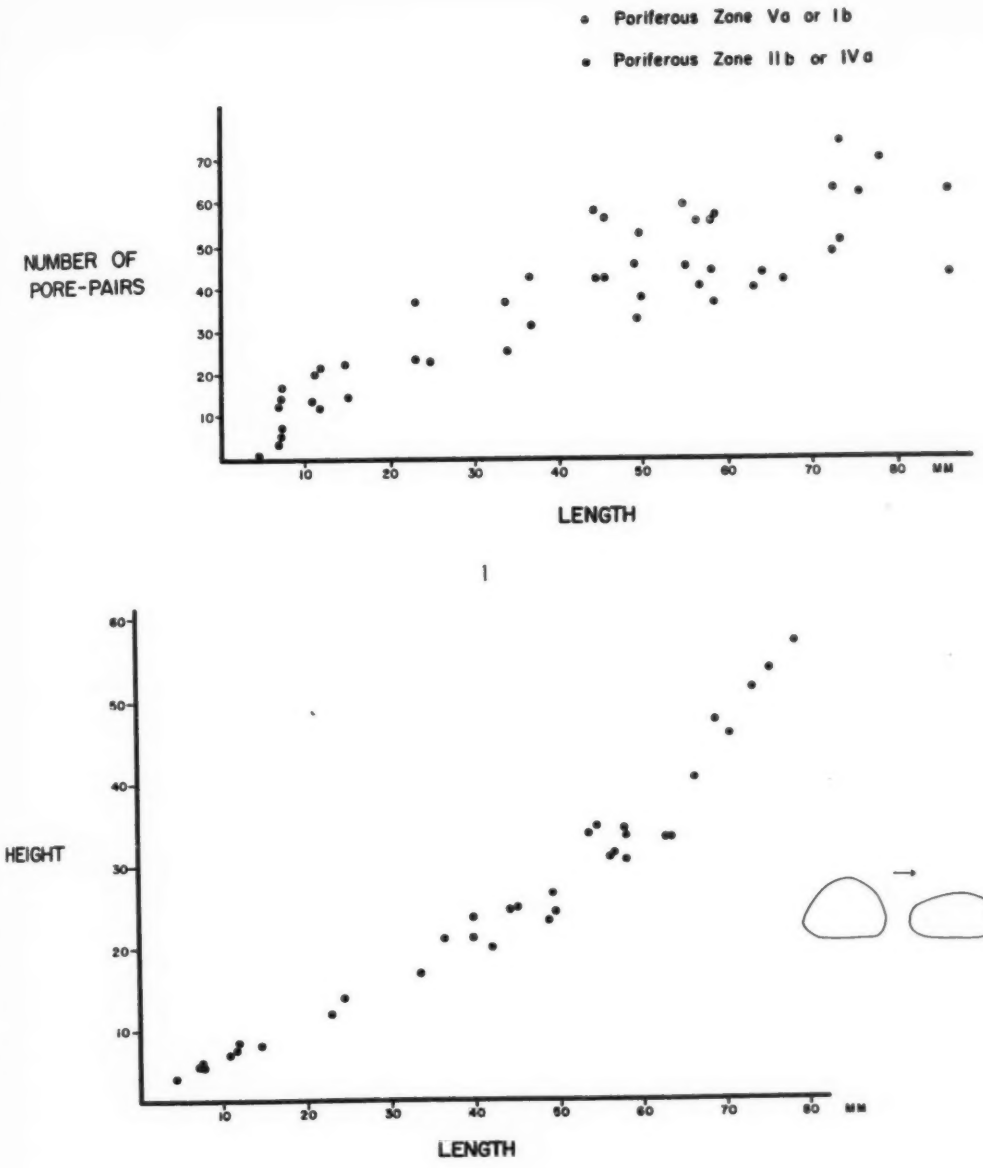
The width relative to the length, however, is not as variable as the height. In text-fig. 4-2, the points are quite concentrated. From text-fig. 5 the per cent width of length (W/L×100) relative to length, it is apparent that there is a slight decrease in width relative to length in the larger specimens. The width varies from 75 to 90 per cent of the length.

While it is apparent that all the species in this group belong to the same species, it would not be so apparent if such a large number of specimens had not been available for study, and if they had not come from the same locality. Checchia-Rispoli (1950, p. 24–29) did not have this advantage when he described specimens from this species-group. As a result, he considered that three different species were represented. His largest specimen he correctly referred to *E. fraasi*. However, he erected two new species *E. migiurtinus* and *E. migliorinii* for smaller specimens of different shape which are in reality only young specimens of *E. fraasi*. In the collection from Tug, near Pool, Buran, there are specimens which are identical with his types of these two species. His species only differ between each other in their shape. Their petal arrangement, position of apical system, periproct, and peristome are all similar. In any case, the name *Echinolampas migliorinii* had already been used by Venzo (1934, p. 127) for a new species from the Eocene of the Isle of Rhodes.

Checchia-Rispoli (1950, p. 29) described a fourth species of *Echinolampas*, *E. caranoi*, which appears to be quite distinct from this group. It differs in that it has short lanceolate petals, and a larger peristome and periproct.

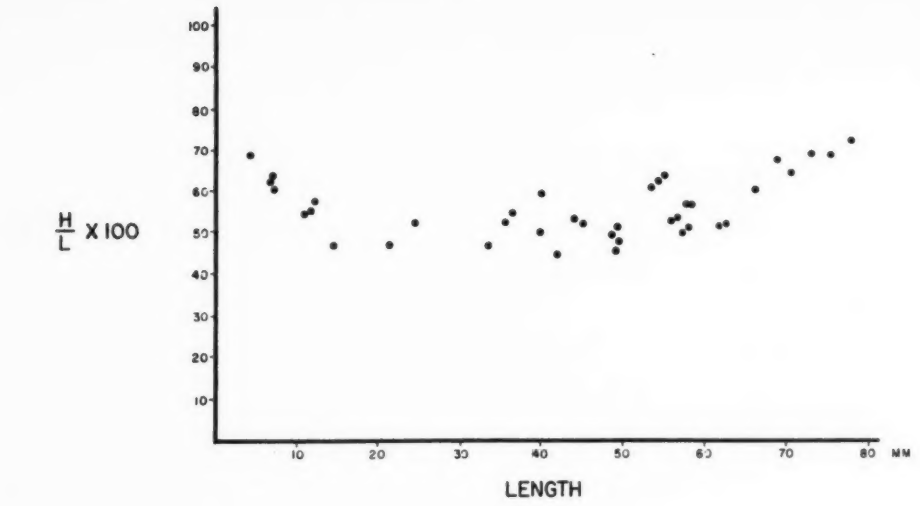
Currie (1927, p. 429) described three small specimens which are identical with some specimens of this species. However, she provisionally referred them to *E. amygdala* Desor, a species very similar to *E. fraasi* but having a more anteriorly eccentric apical system. She pointed out that the apical system in *E. amygdala* was more anteriorly eccentric than in her specimens, but thought that this might be due to variation within the species. However, none of the specimens in this collection have their apical systems as eccentric as *E. amygdala*, but some are eccentric as Currie's. Her specimens, therefore, should be referred to *E. fraasi*.

Abnormality.—One of the specimens,

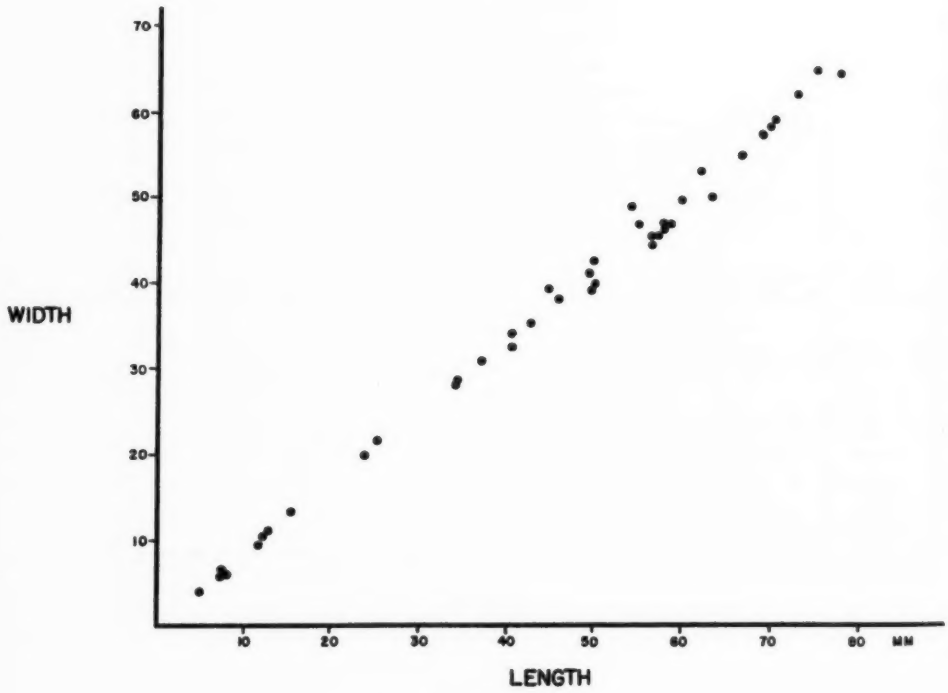


TEXT-FIG. 3

Echinolampas fraasi de Loriol. 1. Number of pore-pairs relative to length. 2. Height relative to length.



1



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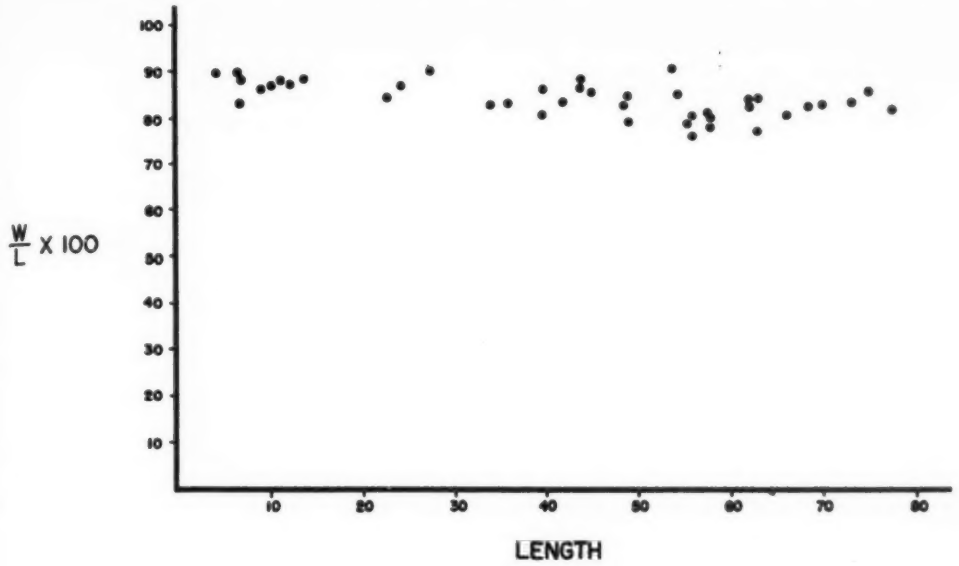
TEXT-FIG 4

Echinolampas fraasi de Loriol. 1, Per cent height of length to length. 2. Width relative to length.



TEXT-FIG 5

Echinolampas fraasi de Loriol. Per cent width of length to length.

C2755, has a very abnormally shaped peristome. There are only four pairs of buccal pores; the buccal pores of ambulacrum V are missing. The position of this ambulacrum is quite normal until near the peristome, where it swings to the left and joins with ambulacrum I just behind its buccal pores. The peristome is very misshapen, being four-sided and higher than wide. Presumably this abnormality is the result of some injury to the echinoid when it was quite young.

Distribution.—Karkar Series (Middle Eocene) of British and Italian Somaliland and Middle Eocene of Egypt.

Localities.—B.6, B.7, B.11, B.14, B.17, B.26, B.27, B.50, B.52, B.54, B.55, B.56, p. 30, p. 15, A.11, T.1, ϕ100, ϕ111, ϕ131, ϕ132, ϕ134, ϕ182, ϕ188, ϕ244, ϕ278, ϕ281, ϕ282, σ167, σ192, σ201a, σ202, (Sedgwick Mus. Cat. Nos. C2616–24, C2714–C2817, C2920, C3179–91, C13354–56).

Genus PLESIOLAMPAS Duncan & Sladen

Plesiolampas Duncan & Sladen 1882. Paleontologia Indica, ser. 14, v. 1, p. 9.

Type species.—By monotypy, *Plesiolampas elongata* Duncan & Sladen.

Diagnosis.—Test small to moderately large, of variable height. Apical system small, usually eccentric anteriorly, with large central madreporite. Ambulacra petaloid, long, narrow, open. In some species, poriferous zones of same petal of unequal length. Peristome eccentric anteriorly; periproct elongated longitudinally. Floscelle moderately developed. Tubercles small, crenulated, with very small, perforate mamelons.

Comparision.—*Plesiolampas* resembles *Echinolampas* and differs mainly in having its periproct elongated longitudinally instead of transversely.

Remarks.—The tubercles of *Plesiolampas* have been considered as being either perforate crenulate, or imperforate noncrenulate. Duncan & Sladen (1882, p. 9) described them as being imperforate noncrenulate in the type species and in their other species from India: *P. placenta, P. ovalis,* and *P. polygonalis.* However, Cotteau (1887, p. 500) found perforate, crenulate tubercles in his *P. heberti* and *P. michelini.* Lambert (1906b) suggested that those species that have been described as having imperforate, noncrenulate tubercles are really species in which the mamelons

are missing and the boss appears to be a mamelon. However, Bather (1904, p. 296) described and figured *P. saharae* as having imperforate, noncrenulate tubercles. Therefore, Mortensen concluded (1948a, p. 314) that both imperforate noncrenulate and perforate crenulate tubercles can be found in different species of *Plesiolampas*.

An examination of Bather's specimens of *P. saharae* in the British Museum of Natural History, B.M.E. 4824–25, 4833–34, revealed that in one well-preserved specimen, B.M.E. 4834, small perforate crenulate mamelons are preserved. Furthermore, in specimens of *P. praelonga* and *P.* cf. *P. ovalis* from the Upper Ranikot of Sind, in the Sedgwick Museum, Cambridge, C3542–45, perforate crenulate mamelons are also present. Finally, they occur in *Plesiolampas curriae* and *P. auraduensis* described below. Surely Lambert was correct in this matter and the "imperforate" species are those in which these tiny mamelons have not been preserved.

PLESIOLAMPAS CURRIAE, n. sp.
Text-fig. 6; Pl. 103, fig. 13,14

Plesiolampas ovalis Duncan & Sladen, Currie (not of Duncan & Sladen) 1925. Mon. Geol. Dept. Hunterian Mus., p. 71, pl. 10, fig. 13.

Diagnosis.—Species characterized by broad marginal outline, rounded in front but with pointed posterior extremity. Greatest width posterior to apical system. Petals short, poriferous zones unequal.

Material.—Most of 268 specimens in collection very poorly preserved. In most cases, apical system and petaloid area completely destroyed, and periproct and posterior extremity broken away. However, enough well-preserved specimens of varying size to permit accurate description of species. Holotype, specimen C3122.

Description.—Dimensions and number of pore-pairs of six specimens are listed in Table 2. Test small, broad, rounded anteriorly; posterior margin pointed. Greatest width posterior of center. Orally, test very depressed around peristome, but inflated in interambulacrum 5. Petals flush or slightly elevated. Apical system eccentric anteriorly, slightly convex; four genital pores, with posterior pores more separated than anterior pores. Madreporite large, central; oculars small, indistinct. Approximately 35 specimens with petals completely visible; poriferous zones usually unequal (text-fig. 6a). In petal III, usually more pore-pairs in IIIa than in IIIb, although in six specimens same number of pore-pairs in each series. In petals II and IV, poriferous zones IIa and IIb with 5–8 more pore-pairs than zones IIb and IVa. In petals I and V, 8–12 more pore-pairs in zones Va and Ib than in Vb and Ia, with only one exception, specimen C3138, with more pore-pairs in Vb and Ia than in Va and Ib.

Both pores of pore-pairs of approximately equal size, circular, transversely conjugate. Interporiferous zones wider than poriferous zones, with greatest width near mid-length of petals, tapering towards end of petals. Beyond petals, single line of pores continues from inner set of pore-pairs. Near peristome, moderate phyllode developed; pores slightly crowded, several plates occluded (text-fig. 6b). Pores do not occur in horizontal sutures, as in ambulacral plates of petals, but on edge of sutures. Peristome large, pentagonal, deeply sunken, transverse, and less

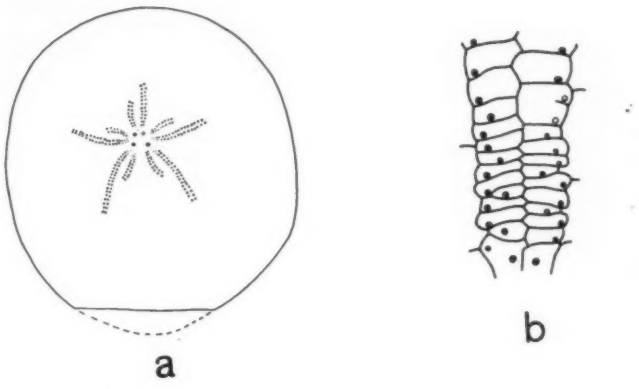
TABLE 2.—DIMENSIONS AND NUMBER OF PORE-PAIRS IN *Plesiolampas curriae* N. SP.

Length (mm.)	Width (mm.)	Height (mm.)	Number of pore-pairs					
			II		III		I	
			a	b	a	b	a	b
14.5	13.1	—	14	7	12	9	11	19
16.2	14.6	8.4	16	9	13	9	10	20
20.5	18.8	9.9	20	15	20	15	19	26
24.0	22.3	12.0	25	17	22	15	—	—
24.2	22.4	10.8	27	18	25	18	22	34
26.9	24.9	10.5	27	22	—	21	24	36

eccentric anteriorly than apical system. Interambulacra within peristome vertical, covered with granules, bourrelets slightly developed. Periproct large, elongated longitudinally, inframarginal, although in some specimens extending aborally to margin. Test covered with small, perforate, crenulate tubercles. Tubercles so sunken in scrobicules that top of boss flush with general surface; mamelons minute, rising slightly above surface of test. The fragile conditions and precarious position of mamelons make them very susceptible to weathering; they are absent in poorly preserved specimens. On aboral surface, tubercles occur in both interporiferous and interambulacral areas. Tubercles not crowded, as intermediate granular spaces usually as large as scrobicules. On oral surface, tubercles crowded into rows; on interambulacrum 5, between periproct and peristome, occurs an indefinite longitudinal track devoid of tubercles and covered with granules.

Comparison.—Currie placed her specimens in *Plesiolampas ovalis* Duncan & Sladen originally described from the Paleocene Ranikot series of India. Her decision was justifiable at the time as she had only one determinable specimen. The study of a large number of specimens has shown clearly that this group represents a new species. While it resembles *P. ovalis* in the position of its apical system, peristome, periproct, and in its general shape; the presence of poriferous zones of unequal length within most of the petals separates it from this species. Only rarely are the poriferous zones in *P. ovalis* unequal and then only slightly. Furthermore, *P. ovalis* has a narrower marginal outline.

P. curriae is easily distinguished from *P. auraduensis* from the Lower Auradu series. *P. auraduensis* has a larger, more elongate, and inflated test. Its petals are longer, narrower, and have straight poriferous zones of equal length. Finally, its petals are more open at their extremities.



TEXT-FIG. 6

Plesiolampas curriae n. sp. a. Aboral view of a young specimen, C3131, showing the unequal poriferous zones of the petals. ×2.5. b. View of the phyllode of ambulacrum I of specimen C13357. ×9.

PLESIOLAMPAS AURADUENSIS, n. sp.
Pl. 104, fig. 2,3,4

Diagnosis.—Species characterized by elongate test with well-rounded margin, widely open petals, with almost straight poriferous zones.

Material.—Three specimens: holotype, C3008, silicified, iron-stained, badly weathered, but showing shape of test; paratype C3010, while badly fractured, shows part of petals; paratype, C3009, badly weathered, partly silicified, but with shape preserved.

Description.—Dimensions of holotype: length 49.8 mm., width 40.0 mm., height 24.0 mm. Test elongate, posteriorly pointed, with greatest width slightly anterior of center; greatest height anterior at apical

system. Test inflated with well-rounded margin. Petals flush to slightly elevated, peristome depressed. Apical system anteriorly eccentric, occurring at highest point of test; four genital pores, with anterior pair closer together than posterior pair, madreporite large, central. All ambulacra petaloid. Petals fairly wide, with wide interporiferous zones, over twice width of poriferous zones. Interporiferous zones widest at ends of petals. Poriferous zones narrow, almost straight, with inner pores circular, outer pores slightly elongated transversely. Petals almost extend to three-quarters distance from apical system to ambitus. Petal III shortest, petals V and I longest. Petals flush to slightly elevated above test. Peristome moderately large, transverse, pentagonal; slightly less eccentric than apical system. Deeply sunken area immediately around peristome; bourrelets slightly developed. Periproct moderately large, inframarginal, elongated longitudinally. Test covered with very small perforate, crenulate, deeply scrobiculate tubercles.

Comparision.—Of all the previously described species of *Plesiolampas* this species resembles most *P. elongata* Duncan & Sladen (1882, p. 10). In general shape and petal arrangement the two species are quite similar. However, *P. auraduensis* is much wider, and its apical system is less eccentric anteriorly.

P. auraduensis also resembles *P. ovalis* Duncan & Sladen (1882, p. 58) from the Ranikot Beds of India. *P. auraduensis* is distinguished from this Indian species by its longer petals, with straighter poriferous zones, larger test, and smaller, more pentagonal peristome. Furthermore, in *P. auraduensis* the test is more inflated at the apical system and the ambitus is more gently rounded.

P. auraduensis only slightly resembles *P. curriae* which occurs at the same locality in British Somaliland. It is larger, has a less pointed posterior extremity, a more inflated test, with a more gently rounded margin, and a less depressed peristome. Finally the apical system in *P. auraduensis* is less eccentric anteriorly, and its poriferous zones are more nearly equal.

Distribution.—Lower Auradu Series (Paleocene) of British Somaliland.

Locality.—ϕ122 (Sedgwick Mus. Cat. Nos. C3008–10).

Suborder Conoclypina Delage and Hérouard
Family Conclypidae Zittel
Genus Conoclypus L. Agassiz

Conoclypus L. Agassiz 1839. Description des Échinodermes Fossiles de la Suisse, pt. 1, p. 61.

Type species.—*Clypeus conoideus* Leske, by subsequent designation of Cotteau 1891, p. 200.

Diagnosis.—Test large, inflated, with rounded marginal outline, flattened oral surface. Apical system central to slightly anterior, with four genital pores. Ambulacra petaloid, long, open, broad, having wide interporiferous zones. All petals similar. Inner pores circular, outer slit-like. No phyllodes, bourrelets conspicuous. Periproct elongated longitudinally. Test covered with many small, irregularly distributed, perforate and crenulate tubercles.

Comparison.—*Conoclypus* resembles *Echinolampas* in both shape and petal arrangement. However, in *Echinolampas* both pores in a pore-pair are similar, whereas, in *Conoclypus* the inner pore is round and the outer slit-like. Also, the periproct in *Conoclypus* is longitudinally elongate, whereas it is elongated transversely in *Echinolampas*.

Conoclypus delanouei P. de Loriol

Conoclypus Delanouei P. de Loriol 1880. Mém. Soc. Physique Genève, tome 27, p. 82–83, pl. 2, fig. 17. P. de Loriol 1881. Palaeontographica, bd. 30, p. 15–16. Cotteau 1891. Palaéont. Francaise, tome 2, p. 219. Fourtau 1898. Mém. Inst. égypt (Égypte), tome 3, p. 646. Fourtau 1899. Bull. Inst. égypt, ser. 3, tome 10, p. 51–55, 2 text-figs. Fourtau 1900a. Bull. Inst. égypt, ser. 4, tome 1, p. 166–167. Fourtau 1909. Mém. Inst. égypt (Égypte), tome 6, p. 129, pl. 7, fig. 19–24. Fourtau 1913. Cat. Invertébrés Fossiles L'Égypte, Terrains Tertiaires, Échinides Éocénes, p. 22, pl. 1, fig. 2. Davies 1935. Tertiary Faunas, v. 1, p. 83, fig. 134b,c.

Diagnosis.—Test very large; flattened in young, but inflated in mature. Greatest height at anteriorly eccentric apical system; greatest width slightly anterior of center. Oral surface flattened; marginal outline varies from almost circular to sub-pentagonal. Petals long, open, almost reaching to ambitus. Interporiferous zones very wide

with greatest width near extremities of petals. Periproct longitudinally elongate, occurring just below ambitus. Peristome central, large, pentagonal, with very well developed bourrelets.

Material.—Nineteen specimens, mostly fragmental.

Remarks.—In this species, as is probably true for the genus, new pore-pairs are added continuously throughout the life of the echinoid. A small specimen has 57 pore-pairs in petal III, a specimen 70 mm. long has 68, and the largest, 120 mm. long, has 84 pore-pairs.

Distribution.—Upper Auradu Series (Lower Eocene) of British Somaliland and Lower Eocene of Egypt.

Localities.—B.64, A.26, ϕ93, ϕ113, σ37, σ39, σ128, and one specimen from AA-1st. Conglomerate, Dagab Shabell, R. H. R. Taylor Collection, Sarl Haud, Nogal Valley. (Sedgwick Mus. Cat. Nos. C2612, C2921–35, C3147).

Order CLYPEASTROIDA (L. Agassiz and Desor) Duncan
Suborder LAGANINA Desor
Family FIBULARIIDAE Duncan
Genus ECHINOCYAMUS (Phelsum) Leske

Echinocyamus (Phelsum) Leske 1778. Jacobi Theodori Klein Naturalis Disposition Echinodermatum, p. 213.

Type species.—*Echinocyamus pusillus*, by subsequent designation of the International Congress of Zoology in Paris, 1948. Bull. Zool. Nomenclature, London, v. 4, p. 519.

Diagnosis.—Test small, usually elongate, but sometimes round. Apical system central, with large madreporite with one madreporic pore. Petals of approximately equal length, with usually oblique, non-conjugate pores. Accessory pores present in ambulacra beyond petals. Peristome small, usually sunken, often pentagonal. Internal radiating partitions usually present.

Comparision.—*Echinocyamus* is very similar to *Fibularia*. The main distinguishing feature between the two is that in *Fibularia* there are no internal radiating partitions. Furthermore, in *Fibularia* the test is usually higher, the periproct is nearer the peristome, and usually there are no accessory pores. I have found in the literature only one *Fibularia*, *F. nigeriae* Hawkins (1912) that had accessory pores. It seems reasonable that the presence of accessory pores and radiating partitions could be related to one another. Certainly the presence of accessory pores must considerably weaken the test of an echinoid, and perhaps the partitions serve to offset this weakness.

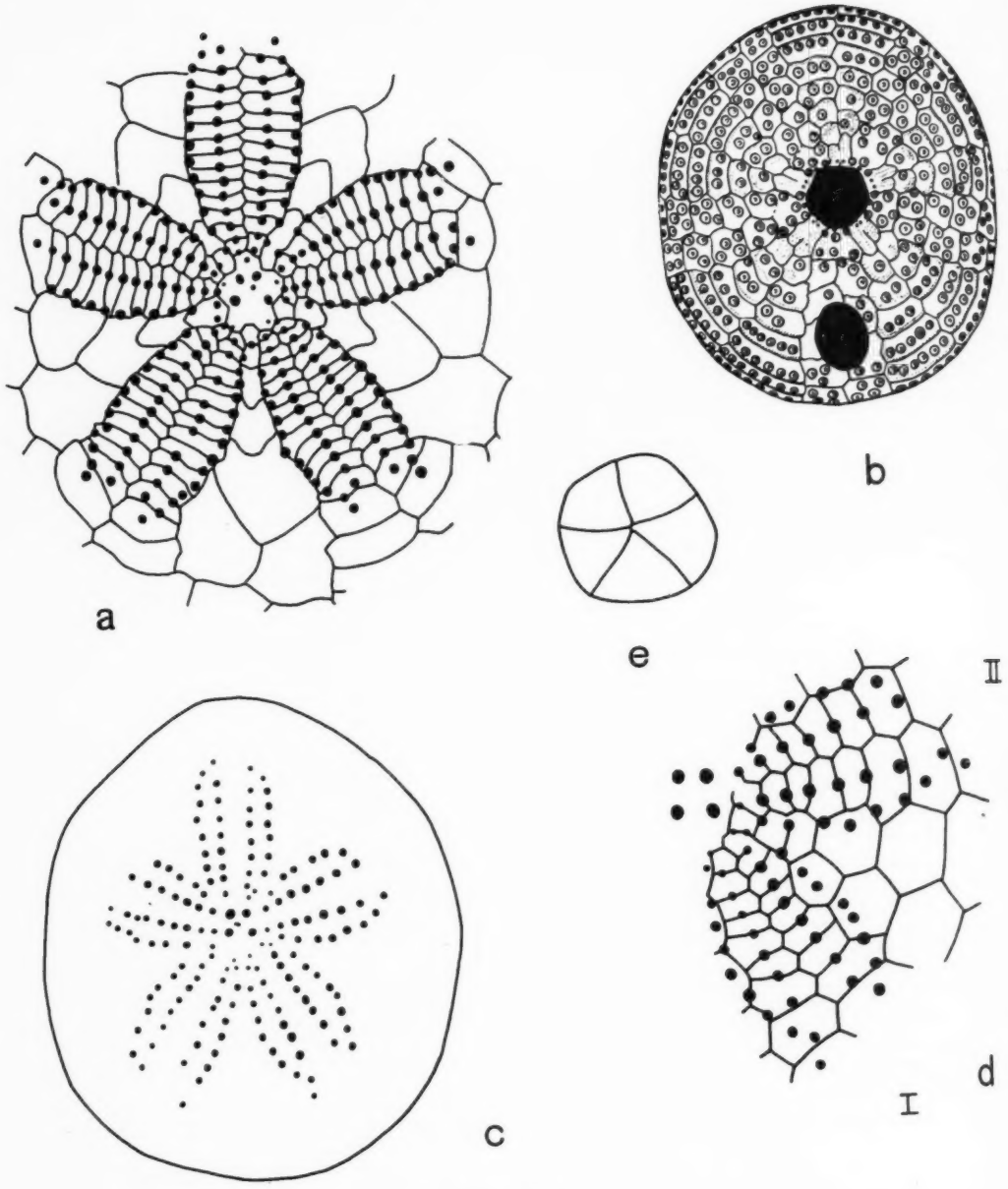
Echinocyamus is very similar to *Sismondia*. However, *Sismondia* can be distinguished by its conjugate pores, with the outer pore of a pore-pair very narrow and slitlike. Furthermore, *Sismondia* has more developed petals than are usually found in species of *Echinocyamus*. Finally the test of *Sismondia* is flatter and more pentagonal, although in some of the larger individuals of the Somaliland specimens of *Echinocyamus polymorpha* the shape of the test appraches that typical of *Sismondia*.

ECHINOCYAMUS POLYMORPHA (Duncan & Sladen)
Text-fig. 1–12, Pl. 104, fig. 5,6,7,8

Sismondia polymorpha Duncan & Sladen 1882. Palaeontologia Indica, ser. 14, v. 1, p. 137.
Sismondia sp. indet. (A) and (B) Currie 1927. Trans. Royal Soc. Edinburgh, v. 55, pt. 2, (no. 18), p. 426–427.

Diagnosis.—Test small, low, with thick well-rounded margin. Apical system slightly eccentric anteriorly. Petals well-developed, wide, (text-fig. 7a) slightly elevated above surface of test; pores large, round, equal, nonconjugate. In most specimens occur simple internal radiating partition walls, usually five pairs proceeding from edge of test and joining auricles. However, in some specimens only posterior partitions present, supporting Mortensen's (1948b, p. 199) contention that character of radiating partitions not diagnostic of a particular species. Periproct (text-fig. 7b) round to slightly elongated longitudinally, usually smaller than peristome, situated near ambitus but in some specimens occurring nearer peristome. Peristome central, pentagonal, depressed.

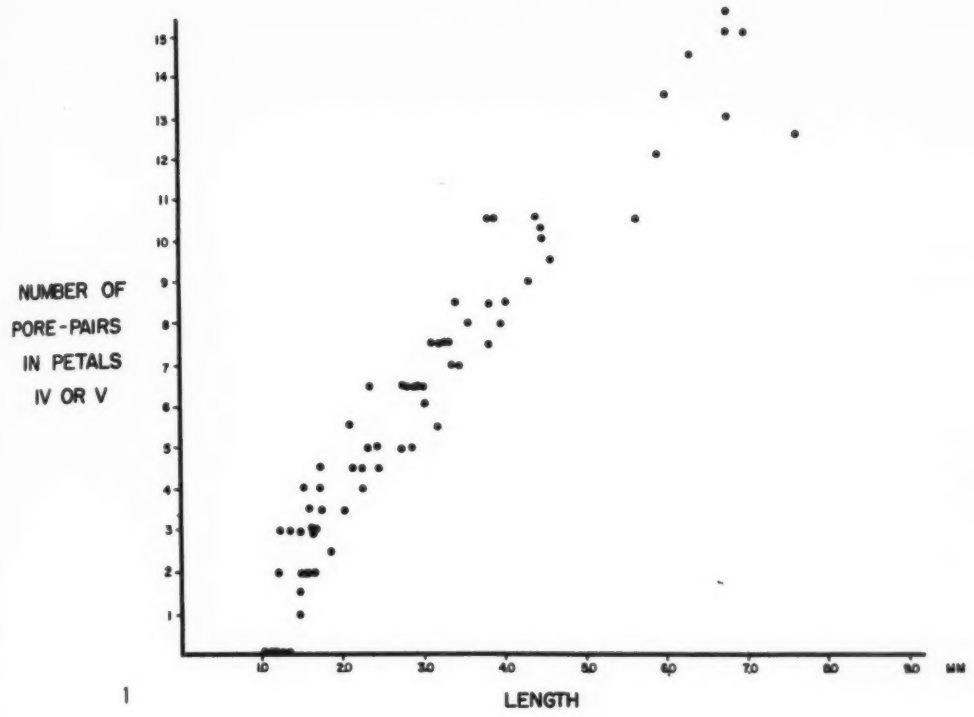
Material.—Over 2,590 specimens and 94 thin limestone slabs containing many specimens. Most of loose specimens well-preserved, although many have portions of their tests covered with matrix. Only few specimens have plate sutures visible. Slabs of limestome often almost entirely composed



TEXT-FIG. 7

Echinocyamus polymorpha (Duncan & Sladen) a. Aboral view of specimen C13358 showing the plate sutures which have been enlarged by weathering. The two pores of a pore-pair are joined obliquely, not parallel to the suture passing through the pores. The inner pore of a pore-pair is nearest the apical system. ×8. b. Oral view of specimen C13359. ×6.

Fibularia dubarensis, n. sp. c. Aboral view of specimen C13362, showing the broad, well-developed petals. ×8. d. Aboral view of specimen C13363, showing the presence of ambulacral pores in some of the interambulacral plates. ×15. e. Periproctal plates in specimen C13364. ×21.



TEXT-FIG. 8

Echinocyamus polymorpha (Duncan and Sladen). 1. Number of pore-pairs relative to length. 2. Length relative to width.

of silicified and iron-stained tests so closely packed together that slab retains its original shape, after being dissolved in hydrochloric acid although only tests remain.

Remarks.—Duncan & Sladen referred their specimens of this species to *Sismondia* as they believed their specimens had conjugate pores, although they stated that the conjugation was scarcely perceptible. It is the writer's opinion that the pores are not conjugate in the Indian specimens, and that Duncan and Sladen may have mistaken the horizontal sutures between the ambulacral plates, which pass through the pores, for conjugation furrows. In most cases of conjugated pores, particularly in the Clypeastroida, the outer pore is elongated transversely into a narrow slit which points towards the other pore of the pair. In Duncan and Sladen's figured specimens of *E. polymorpha* both pores of a pore-pair are round and equal. Therefore it seems probable that their specimens did not have conjugate pores and should be referred to *Echinocyamus*. The author has been unable to examine these specimens.

Growth.—From locality ϕ145, near Yeis Tug, there are a large number of thin limestone slabs which are literally covered with extremely well-preserved specimens of this species. Because of their great range in size, from a length of 0.38 mm. to 9.0 mm., an ontogenetic study of the population was possible.

All the specimens were measured with an ocular scale to the nearest fiftieth of a millimeter. The following dimensions and characters were noted: length, width, length of apical area, length of mouth, distance of periproct from mouth, number of pore-pairs in petals IV and V, and the presence or absence of ocular and genital pores.

None of the specimens with a length less than 1.25 mm. had any pore-pairs. This is somewhat similar to what Mortensen (1907, p. 34) found in his smallest specimen of *E. pusillus*, which had a length of 1.50 mm., but had only one pair of pores. At this early stage, however, pore-pairs are added rather quickly (text fig.8-1) for by the time the echinoid is 2.0 mm. long it usually has 2 pore-pairs. From 2 mm. until full growth, pores are added at a constant rate of about 2.5 pore-pairs for each increase of 1 mm. in length.

The length-width ratio (text-fig. 8-2) is fairly constant throughout the growth of the echinoid. There does, however, appear to be a very slight trend towards a more elongate shape in the larger specimens. There is little variation in width at any particular length, as is shown on the graph by the compactness of the points at any particular point on the graph.

Relatively, the apical system is extremely large in the small specimens, as Gordon (1926b, p. 302) also found to be the case in *Echinus miliaris* and *Echinocardium cordatum*. In a specimen with a length of only 1.2 mm. the apical area is 0.56 mm. long or 46

EXPLANATION OF PLATE 103

All figures ×1

FIG. *1–2*—*Rhabdocidaris* sp. cf. *R. zitteli* de Loriol. *1*, side view of specimen C3151; *2*, aboral view of same specimen.

3—*Porocidaris schmidelii* (Münster). Side view of radiole, C3213.

4,5—*Pedinopsis ? melo*, n. sp., *4*, aboral view of specimen C3007. Most of surface covered with matrix and radioles; *5*, side view of same specimen showing depressed adradial sutures and fine tuberculation.

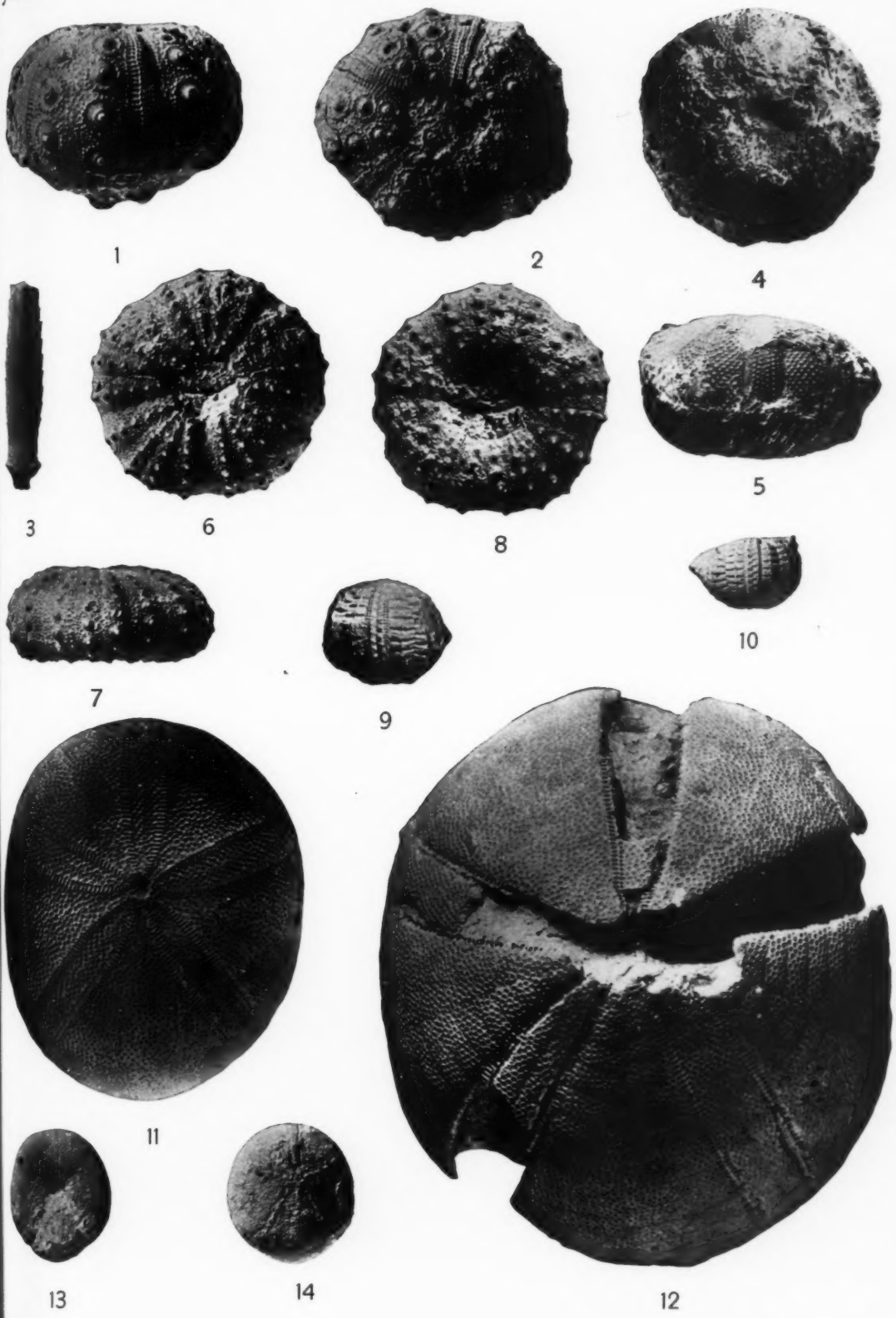
6,8—*Porosoma lamberti* Checchia-Rispoli. *6*, aboral view of specimen C3161 showing subpentagonal shape of test in large specimen. *7*, side view of same specimen; *8*, Oral view of same specimen.

9—*Ambipleurus rotundatus* n. sp. Side view of holotype, C3146, showing bow-like appearance of interambulacral plates.

10—*Ambipleurus douvillei* (Lambert). Side view of specimen C2978.

11,12—*Echinolampas fraasi* de Loriol. *11*, aboral view of specimen C2763. *12*, aboral view of specimen C2621.

13,14—*Plesiolampas curriae*, n. sp., *13*, oral view of specimen C3129; *14*, aboral view of holotype, C3122.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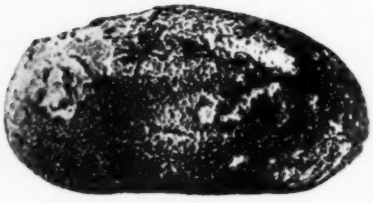

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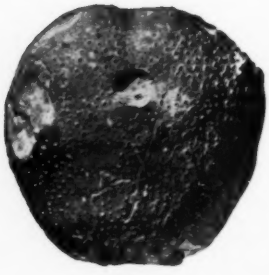

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per cent of the length. The apical system does not increase in size until the animal is more than 2 mm. long, and then at a rate so slow that a specimen with a length of 7.03 mm. has an apical system only 0.69 mm. in length, or only 9.8 per cent of its length. This relation is shown very clearly in text-fig. 9. The smallest specimen with genital pores is 2.49 mm. long. The pores must appear very quickly as I have found no specimens with small pores.

The growth of the peristome is very similar to the growth of the apical system (text-fig. 10). In the smallest specimen it is also extremely large, 60 per cent of the length of the echinoid, and as the animal grows the peristome becomes relatively smaller until when the echinoid is 4 mm. long the peristome is only 18 per cent of the length. It maintains this relative size as the animal grows to full size. The jaws were present in the smallest specimen, one only 0.38 mm. long.

No anal opening is visible in the smallest specimens. Theel (1892, p. 57) found the same in all of his specimens of *E. pusillus* (none of his specimens were over 0.4 mm. long). The smallest specimen with an anal opening is 0.80 mm. long. The periproct on this specimen is on the aboral side. Gradually, as the animal grows, the periproct moves over the ambitus and on to the oral side. By the time the echinoid is 1.50 mm. long, the periproct appears to have reached its adult position.

Summary.—The growth of this species agrees in most respects to what Theel and Mortensen found for *E. pusillus.*

Variation.—As the specimens of *E. polymorpha* occur over a large stratigraphic range from the bottom of the Anhydrite series to the top of the Karkar series, a study of the variation of the group was possible. By simple macroscopic examination of a group of specimens from the two farthest separated horizons, $\phi 129$ high in the Karkar series and $\sigma 257$ low in the Anhydrite series, it is apparent that the specimens from the highest horizon are more elongate with the periproct nearer the peristome, than those from the lowest horizon. This difference is clearly shown in text-fig. 11 in which the points occur in two separate paths. However, the paths are so close together that if the specimens from all the localities between these two extremes were represented it would be impossible to differentiate any of the paths. Therefore, only with statistical methods is it possible to show whether or not these two differences are significant, or whether a definite trend exists between the two extreme populations

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EXPLANATION OF PLATE 104

All figures ×1 except as noted

FIG. *1*—*Echinolampas fraasi* de Loriol. View of left side of specimen C2621, showing inflated test of large specimen.

2–4—*Plesiolampas auraduensis*, n. sp., *2*, aboral view of badly weathered and silicified holotype, C3008, showing large size; elongate shape with long narrow petals; *3*, view of left side of same specimen; *4*, oral view of same specimen.

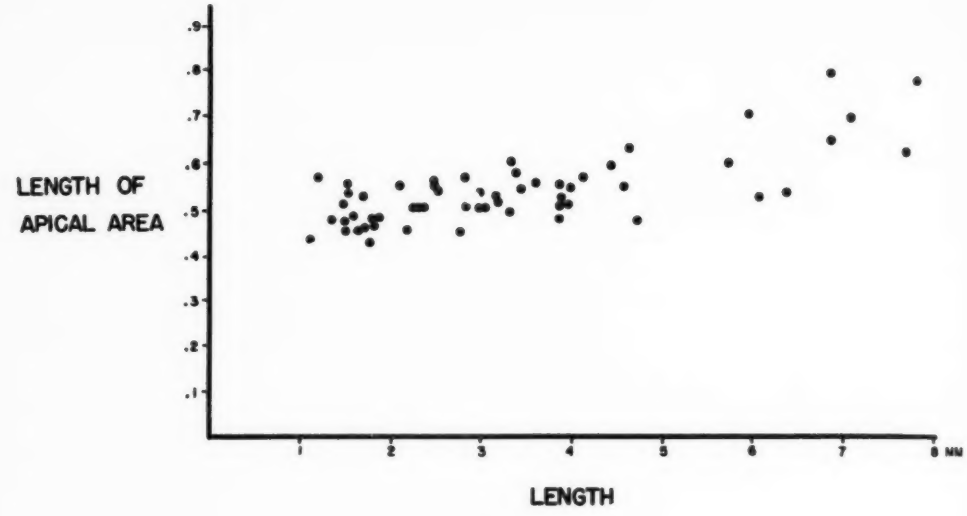
5–8—*Echinocyamus polymorpha* (Duncan and Sladen), *5*, aboral view of specimen, C13360; *6*, oral view of same specimen; *7*, view of right side of same specimen; *8*, enlarged view of aboral surface of same specimen, showing wide, well-developed petals. ×4.

9–11—*Fibularia dubarensis*, n. sp. *9*, aboral view of holotype, C13361; *10*, Oral view of same specimen; *11*, enlarged view of aboral surface of same specimen, showing pointed anterior, blunted posterior margin, and well-developed petals. ×2.

12–13—*Brightonia macfadyeni*, n. sp., *12*, aboral view of holotype, C3061, showing blunted anterior margin, and narrow, straight petals. Track of peripetalous fasciole marked with pencil; *13*, view of left side of same specimen, showing steep anterior surface.

14–16—*Leviechinus gregoryi* (Currie), *14*, aboral view of specimen C3020, showing smooth test with straight flush petals, and fine tuberculation. Track of peripetalous and marginal fascioles marked with pencil; *15*, View of right side of same specimen showing highly inflated test, and portions of both peripetalous and marginal fascioles; *16*, oral view of same specimen.

17—*Pharaonaster* sp. cf. *P. ammon* (Desor). View of right side of specimen C2613 with peripetalous fasciole marked with chalk.



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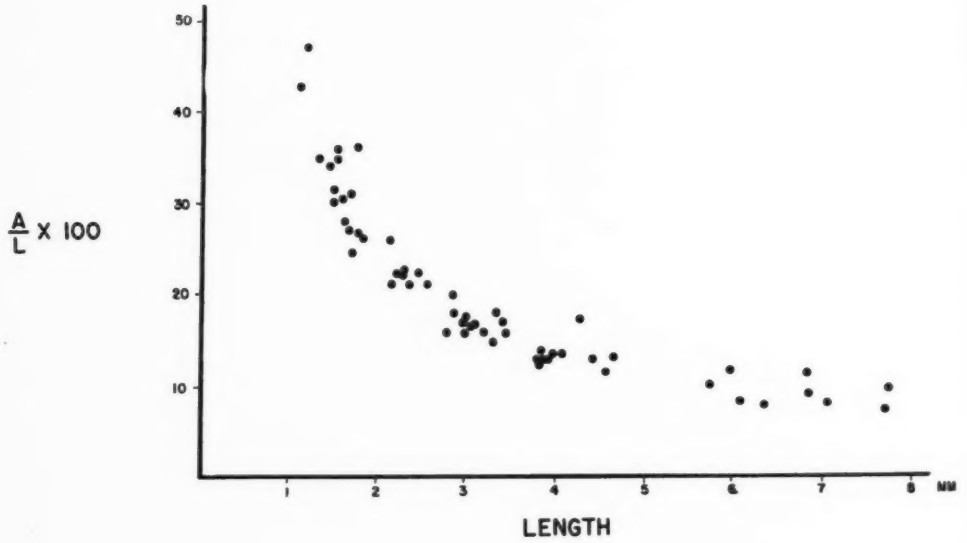

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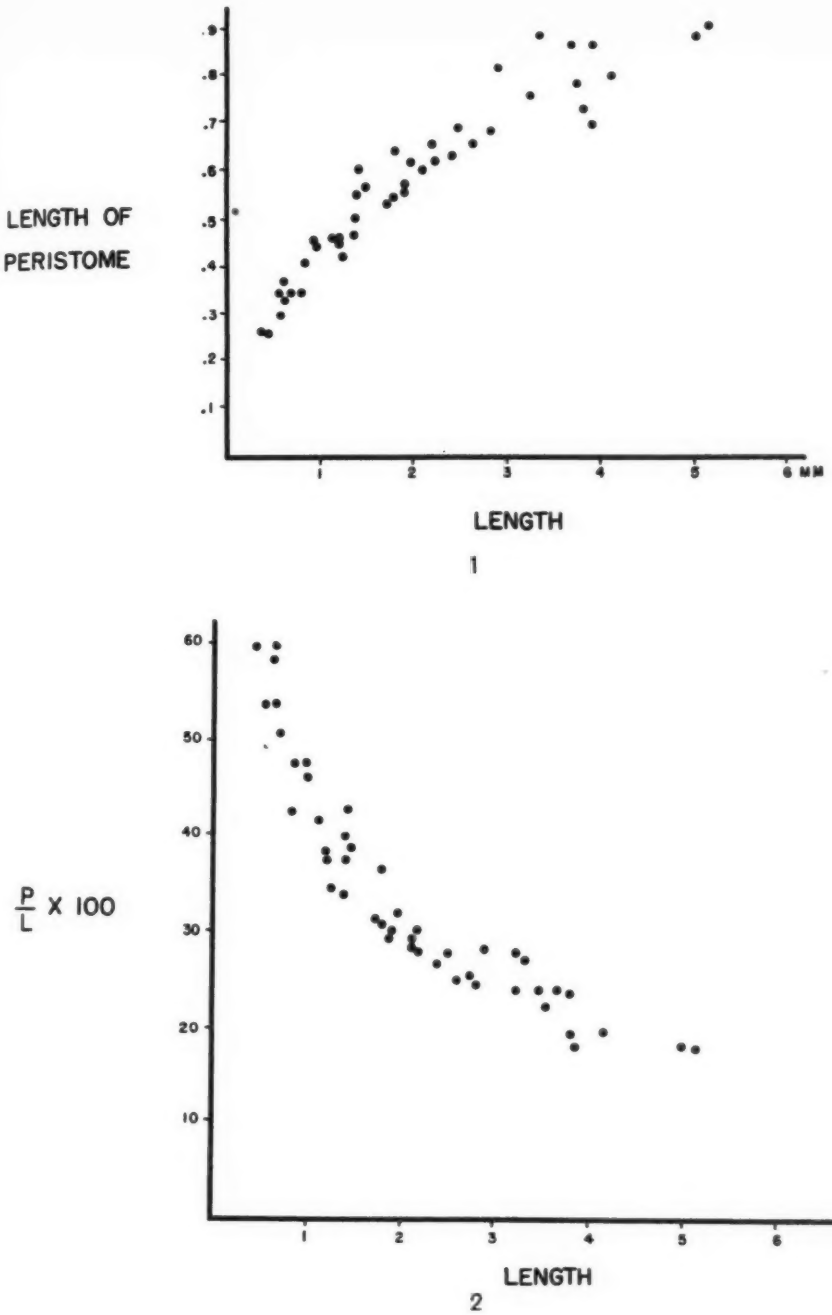
TEXT-FIG. *9*

Echinocyamus polymorpha (Duncan & Sladen). 1. Length of apical area relative to length. 2. Percentage relation of length of apical area to length.



TEXT-FIG. *10*

Echinocyamus polymorpha (Duncan & Sladen). 1. Length of peristome relative to length. 2. Percentage relation of length of peristome to length.

TABLE 3.—SPECIMENS MEASURED FROM LOCALITY ϕ277

Length (mm.)	Number of specimens	Mean length / Mean width
>9.5	18	1.094
7.5–9.5	220	1.068
6.5–7.5	69	1.061
5.5–6.5	17	1.044
Total 5.5>9.5	324	1.069

Average length—8.1 mm.

Whereas there are over forty localities from where more than ten specimens each were collected, only specimens from nine of these were used. All the other localities, particularly those of the Barrington Brown Collection, were not well enough located in the stratigraphic section to be of use in this study. As many of the specimens are partially covered with matrix, it was possible to compare only two factors, the per cent width of length and the distance of the periproct from the mouth. In only one of the populations, ϕ145, was it possible to count the number of pore-pairs or measure the length of the apical system and mouth.

The length and width of the specimens were measured to the nearest tenth of a millimeter with a caliper, and the distance (P) from the mouth to the periproct was measured to the nearest fiftieth with an ocular scale. The mean of the length divided by the width, and P divided by the length was calculated and their standard deviations determined.

Length-width ratio.—The validity of any system of correlation by means is dependent upon whether the mean is constant throughout growth within one population. If the length-width ratio varied, for example if the specimens became more elongate as they matured, then a population of large specimens could not be expected to have the same ratio as a population of small specimens. Therefore all the complete specimens were measured of two of the largest populations, and the results were divided into different size groups.

TABLE 4.—SPECIMENS MEASURED FROM LOCALITY ϕ276

Length (mm.)	Number of specimens	Mean length / Mean width
7.5–9.5	176	1.111
6.5–7.5	132	1.097
5.5–6.5	88	1.096
5.5	37	1.087
Total 5.5–9.5	433	1.102

Average length—7.3 mm.

It is clear from the above tables that the larger specimens are more elongate than the small, and that a population of small specimens will have a different L/W mean than a population of large specimens. However, the fact that most of the specimens are from 6–8 mm. long in all the populations lessens the effect of this growth change.

Also from the above tables it is apparent that the means of the L/W of the two populations are quite different: ϕ277 has a mean of 1.069 with a standard deviation of .036, whereas ϕ276 has a mean of 1.102 with a standard deviation of .045. Whether or not this difference is significant is found by the following procedure (Burma, 1948, p. 731).

$$\sigma_d = \sqrt{\frac{\sigma_1^2}{N_2} + \frac{\sigma_2^2}{N_1}}$$

$$\sigma_d = \sqrt{\frac{(.036)^2}{433} + \frac{(.045)^2}{324}}$$

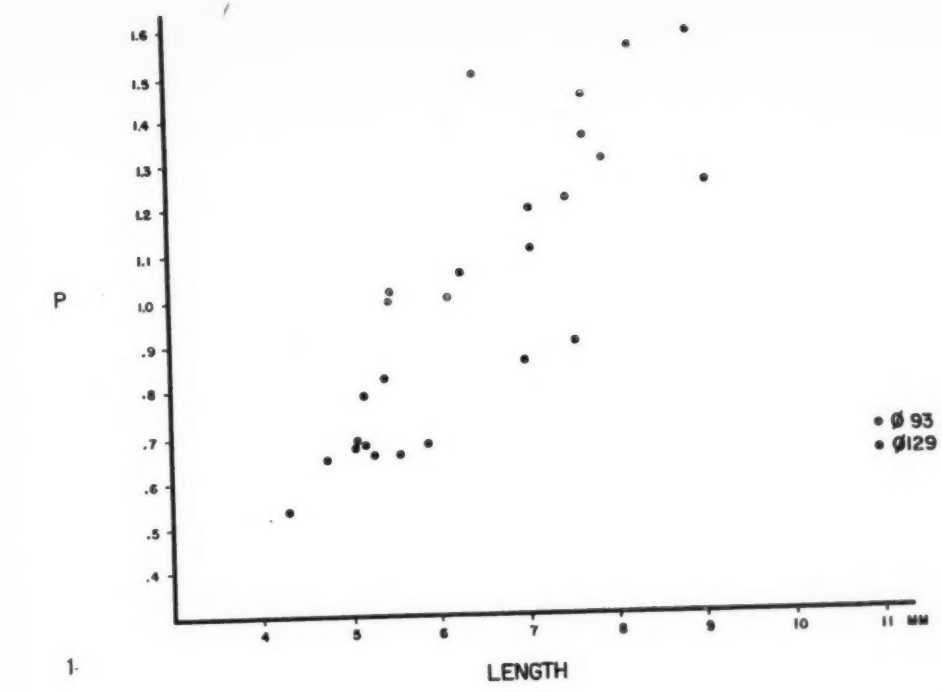
$$\sigma_d = .0030$$

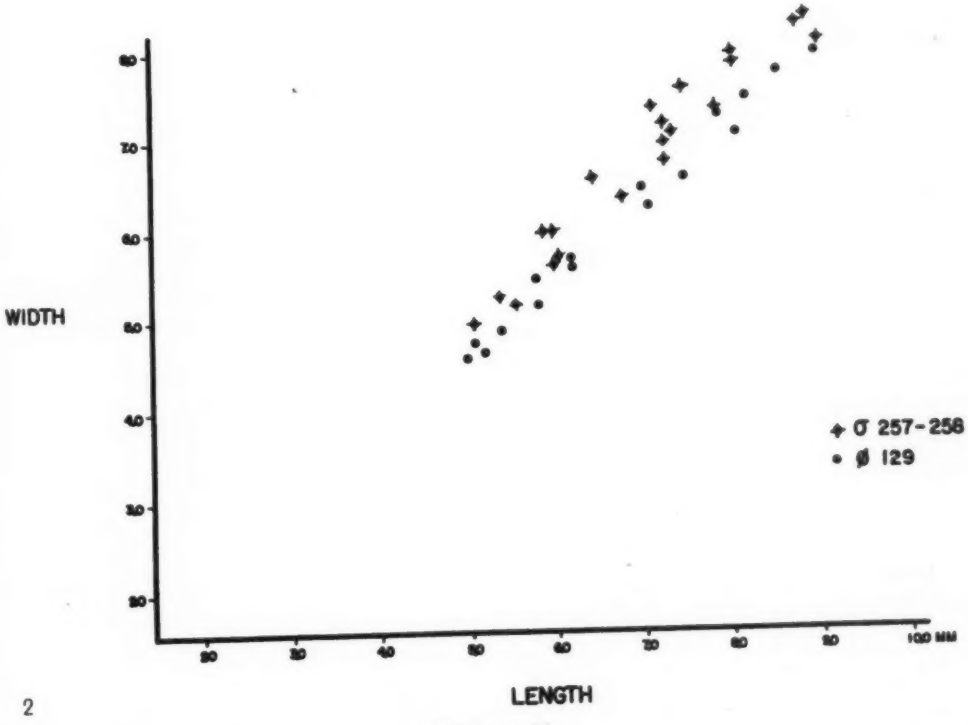
σ = standard deviation
N = number of specimens
$\sigma_1 = 0.36$
$\sigma_2 = .045$
$N_1 = 324$
$N_2 = 433$

"Next d is found by subtracting the smaller arithmetric mean from the larger. Then d is divided by σ_d. If the resultant is less than 2.0 ($P = 0.955$), the difference between the means is probably not significant, this probability increasing as the number decreases. If the answer is between 2.0 and 3.0 ($P = 0.955$ to $P = 0.997$) the difference is possibly significant. If the result is 3.0 or more ($P = 0.997+$) the difference is almost certainly significant, the degree of probability increasing rapidly with the increase in the number."

$$\frac{d}{\sigma_d} = \frac{.033}{.0030} = 11.0$$

Obviously the difference of the means is very significant. Since the average length of the specimens from ϕ277 is 8.1 mm. as compared to 7.2 in ϕ276 ,the difference be-





TEXT-FIG *11*

Echinocyamus polymorpha (Duncan & Sladen). 1. Relation of distance of periproct from peristome of specimens from localities ϕ129 and ϕ93. 2. Length relative to width of specimens from localities ϕ129 and σ257–258.

TABLE 5.—COMPILATION OF MEASUREMENTS OF 944 SPECIMENS OF ECHINOCYAMUS POLYMORPHA

Locality	Length-width relation					Position of periproct		
	Number of specimens	Average length (mm.)	$\frac{L}{W}$	$\frac{W}{L}\times 100$ (per cent)	Standard deviation of $\frac{L}{W}$	Number of specimens	Per cent P of length $\frac{P}{L}\times 100$	Standard deviation (per cent)
ϕ129	20	6.9	1.131	88	.028	16	13	1.9
ϕ125	52	7.4	1.127	89	.031	26	13	1.4
ϕ270	16	5.3	1.126	89	.026	—	—	—
ϕ99	36	6.2	1.115	90	.038	20	12	1.6
ϕ258	24	5.9	1.113	90	.024	15	17	2.3
ϕ276	433	7.2	1.102	90	.042	44	17	2.6
ϕ93	16	7.5	1.070	93	.030	10	18	2.1
ϕ277	324	8.1	1.069	93	.034	68	20	2.6
σ257–258	23	7.3	1.059	94	.031	—	—	—

tween the means would be even greater if the specimens had been of equal size.

Most of the other specimens in the seven other localities were measured and their mean L/W and standard deviation determined. The results are tabulated in stratigraphic order in Table 5 with the lowest horizon at the bottom of the chart and the highest at the top. There is a constant trend with the specimens becoming more elongate up the stratigraphic column. These results are also illustrated in the included strata sections (text-fig. 12) adapted from Macfadyen (1933).

Position of Periproct.—In the study of the position of the periproct, it was again necessary to determine whether there was any movement of the periproct during growth.

While there is evidence of a slight change in the position of the periproct during growth, the change is so slight that for all practical purposes it can be ignored.

A comparison of the position of the periproct in two different populations, ϕ277 and ϕ276, is recorded in Table 7.

By the same method used previously, the significance of the difference between these two percentages can be found:

$$\sigma_d = \sqrt{\frac{\sigma_1^2}{N_2} + \frac{\sigma_2^2}{N_1}} \qquad \sigma_1 = 2.6$$

$$\sigma_2 = 2.6$$

$$\sigma_d = .50 \qquad N_1 = 44$$

$$\frac{d}{\sigma_d} = 5 \qquad N_2 = 68$$

The difference of the means is again very significant. The calculation of the mean $P/L\times 100$ for the other localities showed a consistent trend with the periproct moving nearer the peristome (Table 5, and Strata Sections, text-fig. 12).

In order to find what change in the plate arrangement of the oral surface produced the decreased distance between the peri-

TABLE 6.—SPECIMENS MEASURED FROM LOCALITY ϕ277

Length (mm.)	Number of specimens	Mean $\frac{P}{L}\times 100$ (per cent)	Standard deviation (per cent)
9.5	11	19	3.0
7.5–9.5	32	20	2.6
6.5–7.5	21	21	2.1

TABLE 7.—POSITION OF PERIPROCT IN TWO POPULATIONS

	Number of specimens	$\frac{P}{L}\times 100$ (per cent)	Standard deviation (per cent)	Average length (mm.)
ϕ276	44	17.5	2.6	7.9
ϕ277	68	20	2.6	8.1

TEXT-FIG. 12

Stratigraphic sections showing the position of horizons whence were collected the measured specimens of *Echinocyamus polymorpha* (Duncan and Slader). The percent width of length and percent of distance of periproct from peristome is recorded beside each locality number. A consistent trend is evident.

proct and the peristome, all the specimens from localities ϕ129, ϕ181, ϕ125, and ϕ258 were studied. Because the plate arrangement was visible in only a few of the specimens and various techniques of staining and cleaning were unsuccessful, no information was obtained.

Conclusion.—There is a consistent trend in all the populations towards a more elongate shape, and a movement of the periproct towards the peristome. This variation may have been caused by one of two circumstances. In the first instance, the environment may have been changing in a certain definite direction. As the environment changed, those echinoids which were narrowest and had their periprocts nearest the peristome may have been at an advantage, and increased in numbers relative to the others. Gradually, if this environmental change continued, the species would undergo the described trend.

On the other hand, the environment may have remained constant and still the trend could have occurred. If the echinoids had not been perfectly adapted to their environment, this trend may represent their slow adaptation. Perhaps those echinoids with narrower tests had an advantage in burrowing and were favored by natural selection.

There is no systematic significance in this trend. The trend is so slight and the differences between the populations so little as to rule out any attempt to divide the species into varieties.

Distribution.—Anhydrite and Karkar series (Middle Eocene) of British Somaliland, and Middle Eocene of India.

Localities.—ϕ93, ϕ97, ϕ98, ϕ99, ϕ100, ϕ108, ϕ111, ϕ112, ϕ116, ϕ121, ϕ125, ϕ129, ϕ134a, ϕ135, ϕ145, ϕ164, ϕ167, ϕ186, ϕ188, ϕ189, ϕ230, ϕ231, ϕ244, ϕ248, ϕ249, ϕ257, ϕ258, ϕ264, ϕ265, ϕ268, ϕ269, ϕ270, ϕ276, ϕ277, ϕ110, ϕ147, near ϕ278, ϕ279.

A.23, A.25, B.10, B.11, B.12, B.13, B.14, B.16, B.19, B.20, B.21, B.23, B.24, B.25, B.26, B.27, B.28, B.30, B.31, B.56, B.59, H.22, b.20, b.23, b.24, σ124, σ171, σ175, σ176, σ191, σ192, σ250, σ257, σ258, σ260, σ261, (Sedgwick Mus. Cat. Nos. C13358–60).

Genus FIBULARIA Lamarck

Fibularia Lamarck 1815, Hist. nat. anim. sans vert., vol. 3, p. 16.

Type species.—*Fibularia ovulum* Lamarck, by subsequent designation of the Thirteenth International Congress of Zoology, Paris, 1948, Bull. Zool. Nomenclature London, v. 4, p. 519.

Diagnosis.—Test small, high, elongate to sub-circular. Apical system small, central, with large madreporite. Petals often very slightly developed, with few pore-pairs. Pores non-conjugate, usually oblique. Periproct small, usually round, situated on oral surface often near peristome. Peristome usually round, often sunken; no internal partitions, and usually no accessory pores.

Comparison.—*Fibularia* resembles most *Echinocyamus*, from which it is distinguished by the absence of internal partitions, and by its usually higher test. Furthermore, it usually lacks accessory and buccal pores, and its periproct is nearer the peristome. *Fibularia* is distinguished from *Sismondia* by its higher test, lack of internal partitions, its non-conjugate and equal pores, and less-developed petals.

FIBULARIA DUBARENSIS, n. sp.

Text-fig. 7c–e; Pl. 104, fig. 9,10,11

Diagnosis.—Species characterized by high test, oblong in small specimens, sub-pentagonal in large. Petals very broad, well-developed.

Material.—122 specimens, most of them extremely well-preserved. Holotype, specimen C13361.

Description.—Dimensions of 4 specimens (mm):

Length	Width	Height
4.9	4.5	3.4
8.7	7.7	6.2
10.4	9.3	6.2
12.3	11.1	7.2

Outline of test varies from oblong to sub-pentagonal. Small specimens oblong with anterior surfaces only slightly pointed, but larger specimens sub-pentagonal with anterior surfaces pointed, posterior extremities blunted. Oblong specimens with greatest width at center, sub-pentagonal specimens with greatest width anterior. Aboral surface flattened; oral surface convex. Apical system central to slightly eccentric anteriorly, four genital pores arranged in trapezoid with anterior pair closer together than posterior. Two madreporic pores, joined by furrow. Petals well-developed, of about equal length,

with equal non-conjugate pores (text-fig. 7c). Approximately nine pore-pairs in poriferous zone of mature specimen. Pores widely separated near middle of poriferous zone, having tendency to close towards extremities of petals. Pores occur along sutures. Many of outer pores of petals do not occur in ambulacral plates, but pierce interambulacral plates (text-fig. 7d). In ambulacral plates beyond petals occur minute pores, one in each plate; no accessory pores. Peristome situated slightly posterior to center of test; slightly depressed on larger specimens. Peristome round to slightly oblong, longitudinally; slightly larger than periproct. Periproct situated near peristome, small, round. In two specimens, five triangular periproctal plates preserved (text-fig. 7e). Test covered with irregularly distributed primary tubercles occurring in deep scrobicules. No internal partitions.

Comparison.—This species is easily distinguished from all the other species of *Fibularia*, from the Miocene to the present, by its well-developed petals which have their pores widely separated near the midlength of their poriferous zones.

Capeder (1906) described seven new forms of *Fibularia* from the Miocene of Sardinia. Considering the great variability within species of this group, and the almost indistinguishable differences between Capeder's forms, it is probable that they represent a single species. The Somaliland species is distinguished from the Sardinian forms by having steeply sloping sides, with a rather flat aboral surface, as contrasted to the gently sloping sides and inflated aboral surface of Capeder's forms. In *F. dubarensis* the periproct is nearer the peristome, and the oral surface is convex instead of flat.

F. dubarensis is easily distinguished from *Fibularia excavata* H. L. Clark (1945, p. 320) from the Miocene of Fiji. The Fijian form is very flattened, and has a concave oral surface, as opposed to the very high test with convex oral surface of *F. dubarensis*.

Remarks.—Mortensen (1948b, p. 205) refers to Checchia-Rispoli's (1929) species *Fibularia africana* and *Fibularia cyrenaica* in his list of newly described *Fibularia*. Actually, as they have low tests and internal partitions, they should be referred to *Echinocyamus*. Checchia-Rispoli was a faithful follower of Lambert, and considered *Fibularia* as representing those forms with low tests and internal partitions.

Distribution.—Miocene of British Somaliland. Some of echinoids found at locality B.1 with Foraminifera which Nuttall and Brighton (1931, p. 49) stated to be Miocene.

Localities.—B.1, B.42, B.43, and 2¼ miles of 145° from Bunda Ziada (Sedgwick Mus. Cat. Nos. C13361–64).

Order SPATANGOIDA L. Agassiz
Suborder MERIDOSTERNATA (Loven) Mortensen
Family STENONASTERIDAE Lambert

BRIGHTONIA, n. gen.

Type species.—*Brightonia macfadyeni*, n. sp. from the Paleocene of British Somaliland.

Diagnosis.—Genus characterized by small test, angular marginal outline. Anterior surface steeply sloping with only faint anterior groove. Apical system eccentric anteriorly, ethmophractic with two genital pores. Ambulacrum III non-petaloid; petals very narrow, straight. Plastron meridosternous approaching amphisternous.

Comparision.—This genus is very unusual and very difficult to relate to any other genus. Its narrow straight petals are very distinctive features. Having a nearly meridosternous plastron and an ethmophractic, non-intercalary apical system, it should be placed in the Stenonasteridae. However, it does not seem to have much affinity with this group and can be only provisionally referred to it. The only genus in this family that it even slightly resembles is *Iraniaster* Cotteau & Gauthier from the Senonian of Iran. The two are similar in having the labrum separated from the sternum, and the petals slightly depressed. However, in general appearance they are not in the least similar. *Iraniaster* has a distinct anterior groove with wider curved petals, and a central apical system with four genital pores. Its test has it greatest width at the center, not anterior, and its greatest height is posterior to the center instead of anterior. Furthermore, while both genera have meridosternous plastrons, in *Brightonia* the sternum approaches an amphisternous condition with plate 3 of interambulacrum 5 extending almost half as far anteriorly as plate 2, whereas, in *Iraniaster* plate 3 is directly behind plate 2.

In general appearance this genus resembles *Homoeaster* of the family Palaeostomatidae from the Upper Cretaceous of Algeria and Tunis. Both genera have a small heart-shaped test with a steeply sloping anterior surface and fine tuberculation. *Homoeaster* also has narrow, nearly flush petals, and an ethmophractic apical system. Both genera have only a peripetalous fasciole. *Homoeaster* differs from this genus by having four genital pores instead of two, no anterior groove, and subpetaloid ambulacra, In *Homoeaster* petals V and I are slightly longer than II and IV. In *Brightonia* V and I are much shorter than II and IV. Finally *Homoeaster* has an amphisternous plastron as opposed to a nearly meridosternous one in *Brightonia*.

Brightonia slightly resembles *Brissopneustes* of the Micrasteridae from the Upper Cretaceous to Lower Eocene of Europe, India and Madagascar. *Brissopneustes* also has a heart-shaped test with a slight anterior groove and an ethmophractic apical system. Its petals are wide, instead of narrow, its apical system has three instead of two genital pores, and it has a sub-anal fasciole and no peripetalous fasciole. Its anterior surface is not steeply sloping and its plastron is amphisternous, not nearly meridosternous.

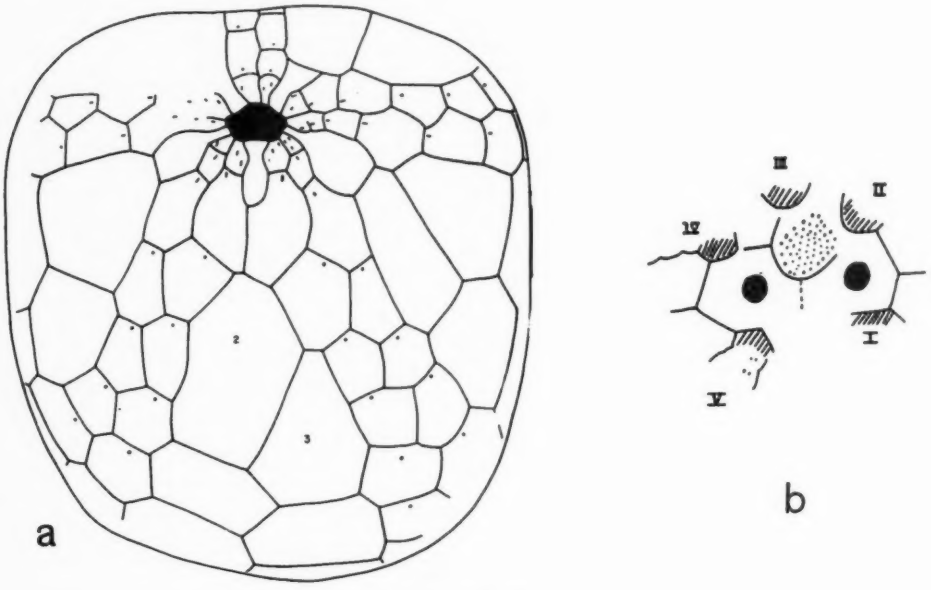
This genus has been compared with all the other genera of the Spatangoida and no similarity worthy of discussion has been found.

BRIGHTONIA MACFADYENI, n. sp.
Text-fig. 13; Pl. 104, fig. 12,13

Material.—Eleven specimens, fractured and weathered: holotype, C3061, with well-preserved aboral surface; paratype, C3055, with plating arrangement of oral surface visible.

Description.—Dimensions (mm.) of three specimens:

Specimen	Length	Width	Height
C3044	25.9	23.7	14.3
C3055	26.4	25.1	17.0
C3057	32.1	30.4	20.6



TEXT-FIG. *13*

Brightonia macfadyeni, n. sp. a. Oral view of specimen C3055 showing the almost meridosternous plastron with plate 3 extending anteriorly alongside plate 2. ×3. b. Apical system of specimen C3059. The oculars are shaded and numbered. The two genital pores occur in genitals 1 and 4. Genital 2 is pierced with madreporic pores. Unfortunately, the plate sutures in the area posterior to the genital pores and between oculars I and V are not visible in this specimen or any of the other specimens. ×13.

Shape.—Test heart-shaped with greatest width anterior to anterior apical system. Marginal outline angular with straight, blunt anterior margin, straight sides converging posteriorly. Posterior surface not truncated. Greatest height at apical system with sides and front sloping steeply to ambitus. Ambulacrum III almost flush with test near apical system, becoming depressed near margin, forming slight groove deepening orally and extending to peristome. Oral surface flat. Apical system anterior, depressed, ethmophractic (text-fig. 13b) with only two genital pores; only genitals 1, 4 pierced. Ambulacrum III non-petaloid with minute pore-pairs. Paired ambulacra straight, extremely narrow, only slightly depressed, petaloid, with conjugate, transversely elongated pores. Interporiferous zones approximately one-half wide as poriferous zones. In petals II and IV, pores in IIb and IVa minute near apical system with 28 pore-pairs in specimen 25.9 mm. long. Petals V and I approximately one-third shorter than petals II and IV, with 22 pore-pairs. Plastron (text-fig 13a) meridosternous, approaching amphisternous as plate 3 extends over one-half as far anteriorly as plate 2. Labrum small, separated from plate 2 by junction of ambulacra V and I. Interambulacra 1, 2, and 3 meridoplaceous, as plate 1 abuts against single plate. In one specimen, C3055, column 4 meridoplaceous, but in all other specimens plate abuts against two plates. Periproct elongated longitudinally, situated on ambitus. Peristome more eccentric anteriorly than apical system, slightly sunken, transverse, subpentagonal. Slightly developed peripetalous fasciole indicated by narrow track of fine granules passing around extremities of petals. Extremely small, perforate, crenulate tubercles scattered irregularly over text; situated within scrobicular circle of milaries. Milaries also occur on ridge separating each pore-pair.

Distribution.—Lower Auradu series (Paleocene) of British Somaliland.

Localities.—ϕ62, ϕ66 (Sedgwick Mus. Cat. Nos. C3029–30, C3044–46, C3048, C3051, C3055, C3057, C3059, C3061, C3062).

LEVIECHINUS, n. gen.

Type species.—*Pericosmus gregoryi* Currie, from Lower Auradu series of British Somaliland. Currie considered the species Lower Eocene, but it is now considered to be Paleocene.

Comparison.—It is very difficult to determine the affinities of this genus. In many respects it is similar to *Somaliaster*, a genus reported from the Cretaceous of British Somaliland, and Iran. The shape of the test of the two genera is similar, both being inflated, with well-rounded sides, and only a slight anterior groove. Both genera have similar petals, flush with the test and slit-like pores. In both genera the test is covered with very small tubercles. *Leviechinus* differs from *Somaliaster* in having a plastron which approaches being amphisternous, as plate 3 extends anteriorly over one-half the length of plate 2 towards the labrum, whereas, as redescribed by K. A. Joysey (1954, p. 46) in *Somaliaster* plate 3 lies directly posterior to plate 2. The apical system is more anterior in *Leviechinus* than it is in *Somaliaster*, and there are only two genital pores in *Leviechinus* and four in *Somaliaster*. Probably *Leviechinus* is a descendent from *Somaliaster*.

The genus resembles slightly some of the other genera of the Meridosternata. In general appearance, because of its heart-shaped test with flush petals and small tuberculation, this genus resembles *Holaster*. In *Holaster* the petals are sub-petaloid and open at their extremities, in *Leviechinus* the petals are well-developed and closed. In *Holaster* the anterior genitals are separated from the posterior genitals, whereas, they are in contact in *Leviechinus*. In *Leviechinus* the sternals are much larger, relative to the other plates of interambulacrum 5, than in *Holaster*.

Among the *Amphisternata*, this genus slightly resembles *Epiaster*. Both genera have a high, finely tuberculated, heart-shaped test. In *Epiaster* the petals are very wide, having wide interporiferous zones, and its test is more pointed posteriorly; in *Epiaster* also, the plastron is amphisternous.

Leviechinus also resembles *Pericosmus*, the genus to which Currie originally referred this species. Both forms have the last plate at the end of their petals occluded, with the younger plates growing up around them, and both forms have a marginal fasciole. However, in *Pericosmus* a definite anterior groove is present, the petals are usually de-

pressed, the test is lower, and the labrum touches both interambulacral plates 2 and 3 in area 5.

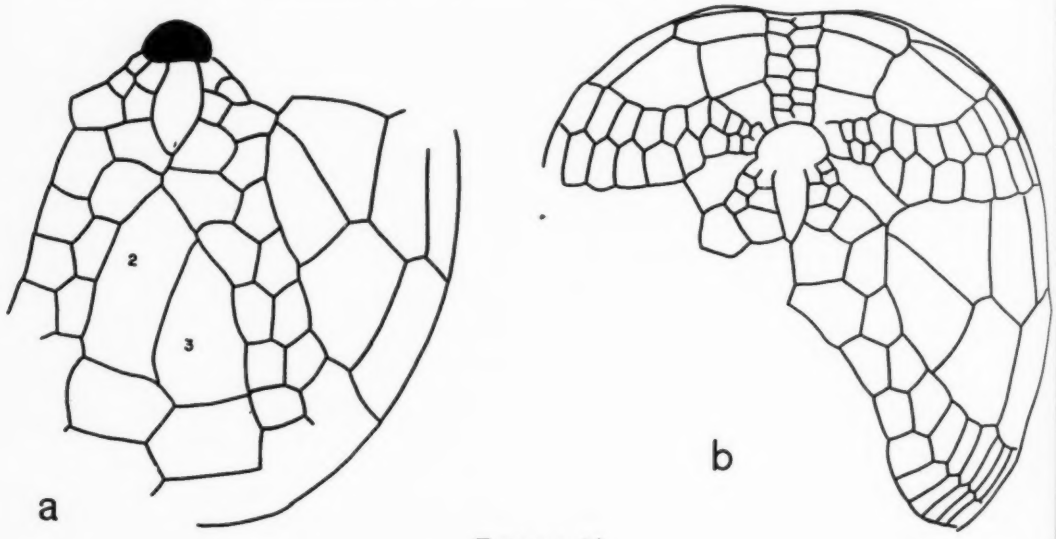
Leviechinus is similar to and no doubt closely related to *Brightonia*. Both genera have interrupted, nearly meridosternous plastrons, flush petals, and fine tuberculation. In *Brightonia* the apical system is ethmophractic, it is ethmolytic in *Leviechinus*. In *Brightonia* the apical system and peristome are more eccentric anteriorly, and the plates at the extremities of the petals are not occluded as they are in *Leviechinus*.

LEVIECHINUS GREGORYI (Currie)
Text-fig. 14; Pl. 104, fig. 14–16

Pericosmus gregoryi Currie 1927. Trans. Royal Soc. Edinburgh, v. 55, pt. 2 (no. 18), p. 430–432, text-fig. 7. Currie 1943, Bull. Am. Mus. Nat. History, v. 82, p. 26–27, text-fig. 10, pl. 4, fig. 5.

Material.—Thirteen specimens similar in all respects to Currie's holotype in the British Museum. In none of the specimens which Currie described was the oral surface visible. From a study of the new material in the Sedgwick Museum it is evident that the plastron is not amphisternous, as Currie presumed, but more nearly meridosternous. It seems advisable to redescribe the species.

Description.—Test very high, inflated, with steeply sloping sides. Marginal outline heart-shaped with greatest width anterior to apical system, greatest height posterior. Oral surface slightly inflated, only slightly depressed around peristome; very slight anterior groove. Apical system slightly anterior to center of test; flush with test. Ethmolytic, with madreporite extending posteriorly; widely separating posterior oculars; two genital pores with only posterior genitals pierced. Ambulacrum III non-petaloid, flush with test near apical system, in slight groove crossing ambitus and continuing to peristome. Ambulacra II and IV, and V and I petaloid, flush with test in small specimens, slightly depressed in larger specimens. Pore-pairs elongate, slit-like, conjugate, with extremely narrow interporiferous zones. Petals II and IV slightly longer than petals V and I; very divergent. Plates at extremities of petals occluded. Plastron (text-fig. 14a) meridosternous, but might be considered incipient amphisternous as plate



TEXT-FIG. *14*

Leviechinus gregoryi (Currie). a. View of the plastron of specimen C3050 showing the meridosternous plastron which is almost amphisternous, as plate 3 extends nearly as far anteriorly as plate 2. The ambulacral pores were not visible in most of the ambulacral plates on this specimen. × 2. b. Oral view of specimen C3015. The ambulacral pores have been omitted, for in most of the plates they were not visible. ×2.

3 of interambulacrum 5 extends nearly as far anteriorly as plate 2. Labrum irregular in shape, not extending posteriorly to sternum, but cut off by junction of adjacent ambulacra. Peristome eccentric anteriorly, only slightly depressed, semi-circular. Periproct elongated longitudinally, situated on ambitus, partially visible from above. Portions of slightly developed peripetalous fasciole preserved on some specimens. Presence of fasciole indicated by narrow track of fine granules; uncertain whether or not continuous. On some specimens, below this fasciole, occurs another fine track of granules which may represent portions of marginal fasciole. Extremely small, perforate, crenulate tubercles scattered irregularly over test.

Distribution.—Lower Auradu series (Paleocene) of British Somaliland.

Localities.—ϕ62, ϕ66 (Sedgwick Mus. Cat. Nos. C3011–16, C3018–20, C3038, C3048, C3050).

Suborder AMPHISTERNATA (Loven) Mortensen

Family PALAEOPNEUSTIDAE A. Agassiz

Genus PHARAONASTER Lambert

Pharaonaster Lambert 1920, Mém. Soc. acad. Aube, tome 84, p. 168.

Type species.—By original designation, *Macropneustes ammon* Desor.

Diagnosis.—Test large, inflated, with slight anterior groove. Posterior truncation very slight, oblique, with periproct not visible from above. Apical system slightly anterior, ethmolytic, with four genital pores. Ambulacrum III non-petaloid. Petals long, open, straight, with narrow, equal poriferous zones, wide interporiferous zones. Orally, interambulacrum 5 gently inflated. Peristome anterior, labiate. Both peripetalous and subanal fasciole present.

Comparison.—*Pharaonaster* resembles *Stomaporus* in shape and petal arrangement. In *Pharaonaster* the interporiferous zones are very wide and tuberculated; in *Stomaporus* they are very narrow. In *Pharaonaster* the periproct is not visible from above, as it is in *Stomaporus*. A closely related genus, *Thebaster*, was erected by Checchia-Rispoli (1941, p. 392) for species which differ from *Pharaonaster* in being more depressed, and having a broad, and elongated transversely periproct.

PHARAONASTER sp. cf. P. AMMON (Desor)

Pl. 104, fig. 17; Pl. 105, fig. 1,2

Macropneustes Ammon Desor in Agassiz and Desor 1847. Annales Aci. Nat. (3), tome 8, p. 115.

Material.—Two specimens, one, C2613, beautifully preserved, 72.2 mm., long, 66.6 mm. wide, and 47.3 mm. high. The other, C2968, badly preserved, not used in this discussion.

Remarks.—This specimen is very similar to *Pharaonaster ammon*, from the Lower Eocene of Egypt. It is similar in its petal arrangement, position of apical system, periproct, and peristome. It also has a slight anterior groove, its greatest width in line with its apical system, and its greatest height posterior to the apical system. It differs only in having a more pointed posterior extremity, with a higher truncation, and a more rounded margin, with a more inflated plastron.

This specimen is also very similar to *Pharaonaster migliorinii* described by Checchia-Rispoli (1941, p. 388) from the Eocene of Italian Somaliland (Migiurtinia). It differs only in being not as high, less pointed posteriorly, and in having the interporiferous zones of petals II and IV narrower at the ends of the petals. These differences are all so slight that it seems probable that *P. ammon*, *P. migliorinii*, and this specimen, all belong to the same species, but this suggestion can be tested only when more specimens are available.

A subanal fasciole is present on this specimen. Until this time it had been uncertain whether or not this fasciole was present in this genus.

Distribution.—Upper Auradu series (lower Eocene) of British Somaliland.

Localities.—B.64, and Camp 7 (Sedgwick Mus. Cat. Nos. C2613, C2968).

Family HEMIASTERIDAE H. L. Clark

Genus OPISSASTER Pomel

Opissaster Pomel 1883, Class. met. Genera des Echinides vivant et fossiles, p. 37.

Type species.—By original designation, *Opissaster polygonalis* Pomel.

Diagnosis.—Test small, with greatest height posterior to apical system. Posterior margin truncated; anterior margin grooved. Petals depressed, straight to slightly flexu-

ous, with petals II and IV longer than V and I. Apical system central, ethmolytic, with two or three genital pores. Peripetalous fasciole present.

Comparison.—*Opissaster* resembles *Hemiaster* as both genera have short, high tests, with well-developed petals. *Hemiaster* does not have a pronounced anterior groove, and its petals are shallower and straight; they are usually flexuous in *Opissaster*. The apical system of *Hemiaster* is ethmophractic with four genital pores, while it is ethmolytic with two, three, or four genital pores in *Opissaster*.

OPISSASTER FARQUHARSONI Currie

OPISSASTER FARQUHARSONI Currie 1927. Trans. Roy. Soc. Edinburgh, v. 55, p. 438–441, pl. fig. 4; Mortenson 1950. A Monograph of the Echinoidea v. 1, Spatangoida 2. Copenhagen, p. 403.

Diagnosis.—Test large, inflated, with deep anterior groove. Petals narrow, deeply sunken; petals II and IV very divergent, slightly flexuous, longer than petals V and I. Apical system anteriorly eccentric, ethmolytic with four genital pores. Periproct situated at top of posterior face; elongated longitudinally. Peripetalous fasciole present.

Material.—Seven specimens or fragments of specimens identical with specimens in British Museum of Natural History described by Currie from the Allahkajid beds of eastern British Somaliland.

Remarks.—Mortensen (1950, p. 403) says "*O. farquharsoni* having four genital pores is not a true *Opissaster*, it should rather be referred to *Trachyaster*." However, Currie was well aware that *Opissaster* usually had only two genital pores. In extensive remarks on *O. farquharsoni*, Currie discusses in great detail the generic relationships of her species. She refers the species to *Opissaster* with some hesitation but explains clearly why she has done so. The petals are narrow and deep, a character of *Opissaster* but not of *Hemiaster* (*Trachyaster*). She does not consider the number of genital pores to be an important character. Duncan & Sladen (1888, p. 332), and Bather (1904, p. 298) and many others have all commented on the unreliability of the number of genital pores as a character of generic distinction. Mortensen, in referring this species to *Trachyaster*, only because it has four genital pores, is in effect saying that the only essential differences between *Opissaster* and *Hemiaster* (*Trachyaster*) is in the number of genital pores. This is not true as Currie points out: "in *Opissaster* the ambulacral petals are deep and the anterior pair flexuous as in *Schizaster*, whereas, in *Trachyaster*, as *Hemiaster*, the ambulacral petals are comparatively shallow and the anterior pair almost straight and very divergent." Mortensen (1950, p. 401–402) himself says "the petals are a little more flexuous than in *Hemiaster*." It would be most reasonable to follow Currie's advice and consider her species as an *Opissaster*.

Distribution.—Upper Auradu series (Lower Eocene) of British Somaliland.

Locality.—ϕ120 (Sedgwick Mus. Cat. Nos. C3066–67).

OPISSASTER AURADUENSIS, n. sp.

Text-fig. 15a; Pl. 105, fig. 3–5

Diagnosis.—Species characterized by depressed shape, with greatest width near center. Petals II and IV straight, widely separated.

Material.—Seven specimens: holotype, C3024, rather well-preserved although petal IV broken away, peristome fractured; paratype, C3023, with well-preserved oral surface, but other specimens poorly preserved.

Description.—Dimensions (mm.) of type specimens:

Specimen	Length	Width	Height
C3023	34.1	32.1	22.3
C3024	37.7	34.4	20.1

Test oval, depressed, with gently sloping sides. Anterior margin grooved, posterior extremity obliquely truncated. Greatest width near center, greatest height midway between center and posterior truncation. Sternum inflated. Apical system situated near center of test, slightly depressed, ethmolytic (Text-fig. 15a), with madreporite extending posteriorly separating posterior oculars. Apical system visible in five specimens: in four only two genital pores visible, posterior genitals being pierced, however, in C3024 three pores, the madreporite, genital 2, being pierced. Ambulacrum III nonpetaloid, depressed in groove continuing from apical system over ambitus to peri-

stome. Its pore-pairs in circular pits with high ridge separating each pore from its partner. All petals about equally depressed. Petals II and IV straight to slightly flexuous, about one-third longer than petals V and I. Pore-pairs conjugate, slit-like, with narrow interporiferous zones, less than one-half width of poriferous zones. Approximately 28 pore-pairs in petals II and IV, 25 in petals V or I, of a specimen 37.7 mm. long (C3024). Near peristome, pore-pairs rather concentrated. Here, as in ambulacrum III, pore-pairs situated in circular pits with high ridges separating each pore. In ambulacra V and I, on oral surface, each plate inflated at its center, depressed at its sutures. On aboral surface, interambulacra 1, 2, 3, and 4 gently inflated. Interambulacrum 5 gently inflated in two of specimens, but steeply in one. Sternum broad, slightly inflated; labrum wide. Periproct longitudinally elongated, situated high on oblique posterior truncation; partially visible from above. Peristome eccentric anteriorly, labiate, very wide, being almost three times as wide as high. Peripetalous fasciole a wide band passing around extremities of petals. Fasciole curves slightly towards ambitus in interambulacra 2 and 3, almost extending to ambitus where it crosses anterior groove. Fasciole curves slightly towards apical system in interambulacra 4 and 1, but passes straight between petals V and I where crossing interambulacrum 5. No other fascioles present. Tubercles perforate, crenulate. On aboral surface, tubercles small, except in area immediately around petals along each side of ambulacrum III, where considerably larger. Orally, tubercles relatively large, particularly on sternum, where largest nearing labrum.

Comparison.—This species is easily distinguished from all the Eocene species of this genus by its depressed shape, with its greatest width near the center of the test, and its straight anterior petals. It slightly resembles *Hemiaster schweinfurthi* de Loriol (1881, p. 34) from the Lower Eocene of Egypt. It is much more depressed than this Egyptian species, its petals are much narrower, and petals V and I are less divergent.

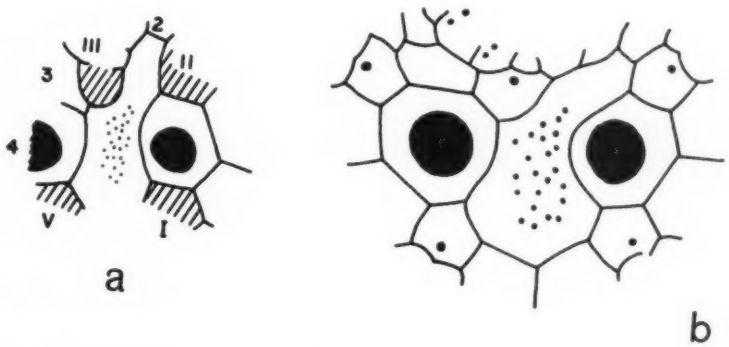
O. auraduensis also resembles the type species, *O. polygonalis* from the Pliocene of Algeria. In general appearance both species are very similar. However, *O. auraduensis* is more depressed, and its petals V and I longer than in the Algerian species.

Distribution.—Lower Auradu series (Paleocene) of British Somaliland.

Localities.—ϕ62, ϕ66 (Sedgwick Mus. Cat. Nos. C3021–25, C3034, C3040, C3058, C3060).

Opissaster somaliensis Currie

Opissaster somaliensis Currie 1925. Mon. Geol. Dept. Hunterian Mus., p. 71–73, pl. 10, fig. 8–12.



Text-fig. *15*

a. *Opissaster auraduensis*, n. sp. The apical system of specimen C3058. The two genital pores occur in genitals 1 and 4. Oculars I, II, III, and V are shaded, but ocular IV and a portion of genital 3 and 4 are missing due to poor preservation. ×13.

b. *Opissaster derasmoi* Checchia-Rispoli. View of apical system of specimen C2655. The genital pores have been greatly enlarged by weathering. ×13.

Diagnosis.—Test small, highly inflated, with pronounced anterior groove, being particularly deep approaching peristome. Posterior extremity slightly truncated obliquely, with periproct occurring high above ambitus, visible from above. Petals slightly depressed; petals II and IV very flexuous, long; petals V and I short, slightly curved. Peripetalous fasciole present.

Material.—All of 248 specimens from same locality, Allahkajid Hill, as those described by Currie.

Comparison.—*O. somaliensis* is somewhat similar to *Opissaster derasmoi* from the Karkar series of Somaliland. It can be distinguished by its deeper anterior groove, especially on the oral surface near the peristome. In *O. derasmoi* the groove is very slight, particularly near the peristome. Petals II and IV are very flexuous in *O. somaliensis* but almost straight in *O. derasmoi*. The test is more inflated in *O. somaliensis* with the greatest height at the apical system instead of posterior to it as in *O. derasmoi*.

O. somaliensis is easily distinguished from *O. auraduensis* by its small inflated test. In *O. auraduensis* the test is very depressed, and quite large. Petals II and IV are quite straight in *O. auraduensis*, in *O. somaliensis* they are very flexuous.

Distribution.—Lower Auradu series (Paleocene) of British Somaliland.

Localities.—ϕ62, ϕ66, ϕ70, ϕ79, σ61, σ63, σ64, σ227 (Sedgwick Mus. Cat. Nos. C3026–28, C3031–32, C3035–37, C3039, C3041, C3047, C3053–54, C3068, C3070–71, C3097, C3117).

OPISSASTER DERASMOI Checchia-Rispoli
Text-fig. 15b; Pl. 105, fig. 6

Schizaster ? cf. *S. symmetricus* Duncan & Sladen, Currie (not of Duncan and Sladen) 1927. Trans. Royal Soc. Edinburgh, v. 55, p. 437.

Opissaster Derasmoi Checchia-Rispoli 1950. Boll. Ufficio Geol. Italia, v. 70, p. 32–35, pl. 1, fig. 6–7.

Diagnosis.—Test inflated, with steeply sloping sides, and oblique posterior truncation. Apical system ethmolytic with two genital pores; system situated slightly posterior of center. Ambulacrum III depressed in slight groove, being very shallow approaching peristome. Petals II and IV slightly flexuous; petals V and I very short, straight; both pairs of petals depressed. Periproct occurs high on posterior truncation. Peripetalous fasciole present.

Material.—149 specimens identical with those described by Checchia-Rispoli from Italian Somaliland. Specimens reasonably well-preserved although many quite weathered.

Remarks.—There is little to add to Checchia-Rispoli's description. In all the specimens in which the apical system is preserved, even the smallest, interambulacral column 2b is isolated from ocular III (text-fig. 15b) indicating that production of interambulacral plates had ceased in this area (Kier 1956). As so few descriptions of species of *Opissaster* include drawings of the apical system, one has been included here (text-fig. 15b).

Currie referred a crushed and broken specimen of this species to *Schizaster* ? cf. *S. symmetricus* Duncan & Sladen. The au-

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EXPLANATION OF PLATE 105
All figures ×1

FIG. *1–2*—*Pharaonaster* sp. cf. *P. ammon* (Desor), *1*, aboral view of specimen C2613; *2*, oral view of same specimen.

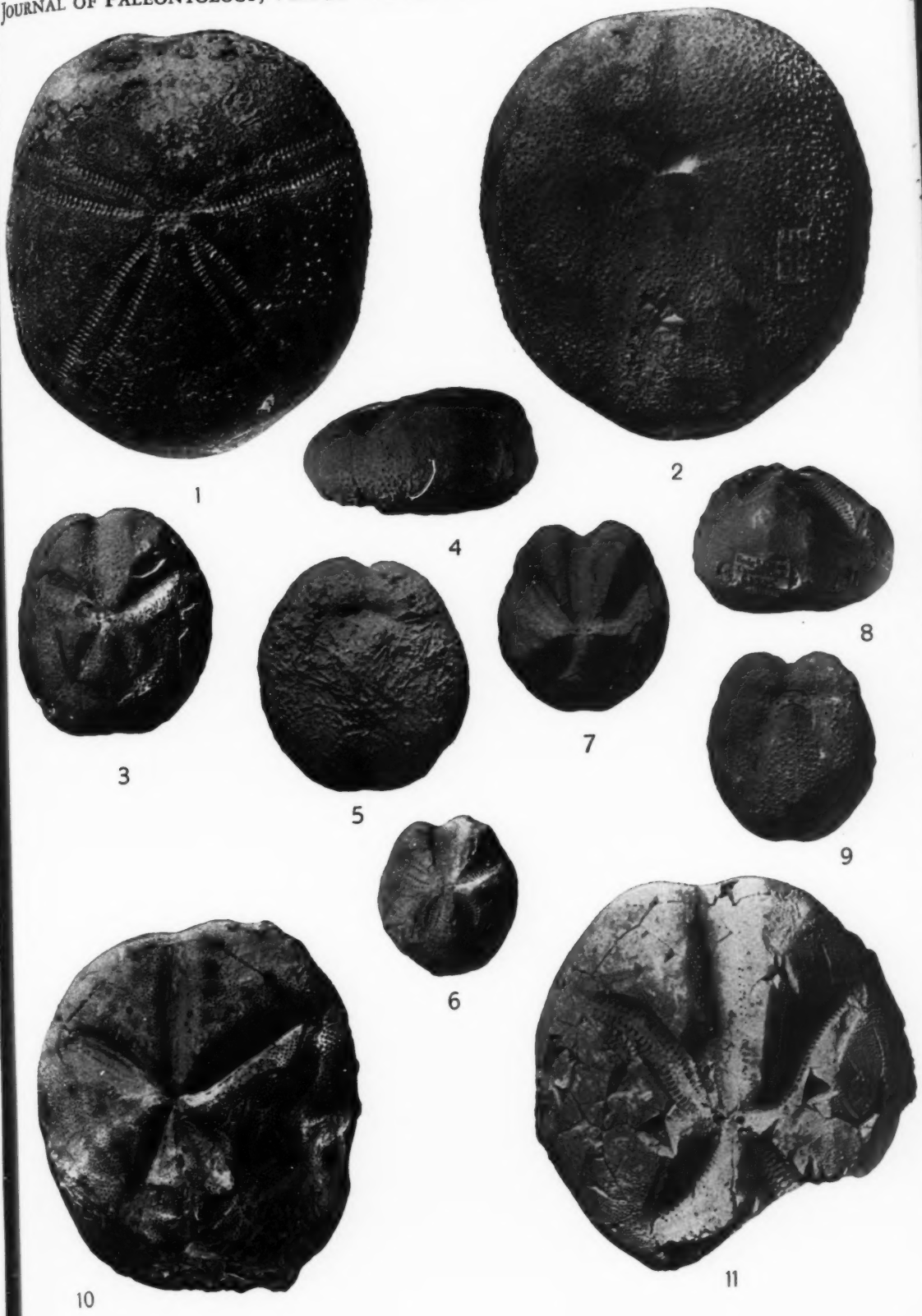
3–5—*Opissaster auraduensis* n. sp., *3*, Aboral view of holotype, C3024, showing broad test, with greatest width near center, and straight petals. Track of peripetalous fasciole marked with pencil; *4*, View of left side of same specimen; *5*, Oral view of same specimen.

6—*Opissaster derasmoi* Checchia-Rispoli, aboral view of specimen C2655.

7–9—*Opissaster derasmoi* var. *angulatus* n. var., *7*, aboral view of holotype, C3205, showing deeply depressed ambulacra, sharply inflated interambulacra 1, 2, 3, and 4, and angular marginal outline; *8*, view of right side of same specimen; *9*, oral view of same specimen.

10—*Hemiaster* (*Trachyaster*) sp., aboral view of specimen C13365. Peripetalous fasciole marked with pencil.

11—*Schizaster africanus* de Loriol, aboral view of specimen C2637.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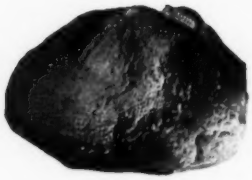

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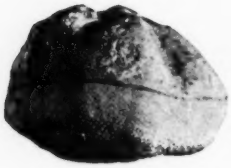

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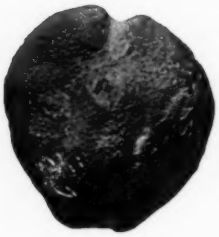

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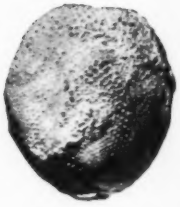

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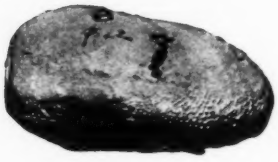

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thor examined this specimen in the British Museum of Natural History and found it to be identical with *O. derasmoi*. Only the oral side is preserved, and it is indistinguishable from this species.

Comparison.—This species very closely resembles *Opissaster digonus* (D'Archiac), (D'Archiac & Haime, 1883, p. 220) from the Khirthar series of India. It is identical in marginal outline, position of periproct, and character of anterior groove with D'Archiac's type specimen. It differs only in that its test is higher, its petals II and IV are slightly more divergent, and its petals V and I slightly less divergent than *O. digonus*. It is not as similar to the specimens of *O. digonus* figured by Duncan & Sladen (1884, pl. 35, fig. 4–10). Their specimens are wider and have wider anterior grooves.

Distribution.—The species occurs throughout the Karkar series of British and Italian Somaliland. It has a wide vertical distribution, occurring at the section at Burud at three widely separated horizons—ϕ244, ϕ255, ϕ258.

Localities.—ϕ109, ϕ115, ϕ131, ϕ132, ϕ182, ϕ244, ϕ255, ϕ258, ϕ269, ϕ270. σ168, σ171, B.5, B.15, B.27, B.51, B.55, B.56 (Sedgwick Mus. Cat. Nos. C2639–41, C2689, C2649–C2713, C3192–94, C3200).

OPISSASTER DERASMOI var. ANGULATUS, n. var.

Pl. 105, fig. 7,8,9

Material.—37 specimens; holotype C3205.

Description.—This variety differs from *O. derasmoi* in the following characters. Ambulacrum III is in a wider, flatter groove, aborally, and in a deeper groove where it crosses the ambitus. The interambulacra are more inflated, forming sharper ridges near the apical system, and in general the test has a more angular appearance. The mouth is typically larger.

This group is so similar in all other features to *O. derasmoi* that it cannot be considered as representing a different species. The petal arrangement, position of apical system, periproct, and peristome, relative dimensions, and number of pore-pairs are the same.

Distribution.—Karkar series (Middle Eocene) of British Somaliland. Most of the specimens of this variety do not come from the same horizons as the specimens of *O. derasmoi*. In only two cases, both rather doubtful as the specimens are very poorly preserved, are the two forms found together at the same locality. Unfortunately, none of the localities where specimens of this

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EXPLANATION OF PLATE 106

All figures ×1

FIG. *1–3—Schizaster* (*Paraster*) ***karkarensis***, n. sp. *1*, aboral view of holotype, C2645, showing deep anterior groove and very divergent petals II and IV; *2*, oral view of same specimen. Plastron somewhat flattened during fossilization; *3*, view of left side of same specimen.

4—Schizaster (*Paraster*) sp. cf. *S. meslei* Peron and Gauthier. Aboral view of specimen C3198.

5–7—Schizaster (*Paraster*) ***hunti***, n. sp., *5*, aboral view of holotype, C13366, showing angular test with greatest width anterior to center, and almost straight petals II and IV. Both peripetalous and lateral-anal fascioles marked with pencil. *6*, view of right side of same specimen. *7*, oral view of same specimen, showing inflated plastron.

8–10—Schizaster (*Paraster*) ***beloutchistanensis*** (D'Archiac). *8*, aboral view of specimen C13367, showing pointed posterior extremity and posteriorly eccentric apical system. Peripetalous and lateral-anal fascioles marked with pencil; *9*, view of left side of same specimen showing obliquely truncated posterior extremity; *10*, oral view of same specimen.

11–14—Schizaster (*Paraster*) ***duroensis***, n. sp., *11*, oral view of holotype C13368; *12*, aboral view of same specimen, showing heart-shaped test and slightly flexuous petals II and IV; *13*, view of right side of same specimen; *14*, aboral view of paratype, C3085, showing peripetalous and lateral-anal fascioles (marked with pencil).

15–16—Linthia somaliensis Currie, abnormality. *15*, aboral view of abnormal specimen, C2944, showing double petal; *16*, Oral view of same specimen showing normal arrangement of plates on oral surface. Part of region around peristome broken away.

17–19—Linthia cavernosa de Loriol. *17*, aboral view of specimen C2638, showing well-developed petals with wide interporiferous zones; *18*, oral view of same specimen showing narrow ambulacra V and I; *19*, view of right side of same specimen.

variety were collected occur on any of Macfadyen's strata sections with localities of *O. derasmoi*. Therefore, it is not possible to know whether the variety occurs above or below *O. derasmoi*.

Localities.—ϕ109, ϕ116, ϕ121, ϕ123, ϕ124, ϕ125, ϕ131, ϕ140, ϕ282, σ190, σ191 (Sedgwick Mus. Cat. Nos. C3201–5).

Genus HEMIASTER Desor
Subgenus *Trachyaster* Pomel

Trachyaster Pomel 1869, Revue des Echinodermes et de leur classification, p. 14.

Type species.—By monotypy, *Trachyaster globosus* Pomel 1869, p. 14.

Diagnosis.—Test small, inflated, with truncated posterior margin, grooved anterior. Apical system ethmolytic with four genital pores. Petals straight, depressed, with petals II and IV longer than V and I. Peripetalous fasciole present.

Remarks.—There has been much controversy and discussion on this sub-genus. Cotteau (1887, p. 400) adopted the genus for all those species of *Hemiaster* which have ethymolytic apical systems. Duncan & Sladen (1888, p. 330) rejected the genus claiming that not only had no type species been designated for it, but the character of the apical system was too variable a feature to be of generic importance. Bather (1904, p. 297) pointed out that Pomel had actually indirectly designated a type but agreed with Duncan & Sladen on the variability of the madreporite. He suggested that *Trachyaster* should be considered as a provisional sub-generic denomination for ethmolytic *Hemiaster*. Lambert (1902, p. 101) rejected *Trachyaster* but later Lambert & Thiéry (1924, p. 507) considered *Trachyaster* as a separate genus. Mortensen (1950, p. 396) also maintains it as a separate genus but admits that the separation is artificial and purely a matter of convenience. It seems more reasonable to consider it as a sub-genus as Bather suggested. This action avoids the possibility that future workers will forget its relationship to *Hemiaster*.

HEMIASTER (TRACHYASTER) sp.
Pl. 105, fig. 10

Material.—23 specimens which appear to belong to this species. Specimens too poorly preserved for definite identification being crushed and flattened to such a degree that original shape not discernible. Regardless of this, specimens of sufficient interest to warrant brief description.

Description.—Apical system depressed, ethmolytic with four genital pores. Ambulacrum III non-petaloid, very depressed forming narrow groove. Petals II, IV curve convexly anteriorly. Petals V, I much shorter, straight. Pores conjugate. Aborally, plates of interambulacra 1, 2, 3 and 4 inflated at their centers, forming ridges that pass from apical system almost to ambitus. Interambulacrum 5 inflated along median suture. Labrum wide, low, continuing posteriorly to middle of second adjacent ambulacral plate. Sternum large, wide, with narrow adjacent ambulacra. Periproct elongated longitudinally, exact position not clear from specimens. Peristome eccentric anteriorly, only slightly sunken, labiate, very wide. Peripetalous fasciole, a very wide band, passing around extremities of petals, curving sharply inward just posterior of petals II, IV. No other fascioles. Small, perforate tubercles scattered irregularly over test. Tubercles on sternum larger, increasing in size posteriorly.

Comparison.—Having an ethmolytic apical system with four genital pores, depressed petals, petals V and I being shorter than II and IV, and only a peripetalous fasciole, these specimens belong in the subgenus *Trachyaster*. Of all the Eocene species, they resemble most *Trachyaster apicalis* (Duncan & Sladen 1884, p. 193) from the Khirthar series of Western Sind. They differ from this species in having petals II and IV curved more convexly in front, in having narrower interporiferous zones, and a more posterior apical system. While these specimens probably represent a new species, their poor preservation prohibits such description.

Distribution.—Upper Auradu series (Lower Eocene) of British Somaliland.

Localities.—ϕ110, σ172 (Sedgwick Mus. Cat. No. C13365).

Family SCHIZASTERIDAE Lambert
Genus SCHIZASTER Agassiz

Schizaster L. Agassiz 1836, Mem. Soc. des Sci. Nat. de Neuchatel, tome 1, p. 185.

Type species.—*Schizaster studeri* Agassiz, by subsequent designation of the Thirteenth International Congress of Zoology in Paris, 1948, Bull. Zool. Nomenclature London, v. 4, p. 527.

Diagnosis.—Test very variable in size, high, truncated posteriorly, anteriorly grooved. Apical system ethmolytic with two, three, or four genital pores. Petals depressed with petals II and IV flexuous, V and I very short, usually straight. Both peripetalous and lateral-anal fasciole present.

Remarks.—According to Mortensen (1951, p. 287) only those species with two genital pores should be referred to *Schizaster*. Unfortunately, it is not clear whether or not the type species *Schizaster studeri* had two or four pores. Cotteau (1886, p. 36) suggested that it had four, although Pomel (1869, p. 14) supposed only two when he erected the genus *Paraster* for species having four pores. Mortensen concludes that the type had only two and states "the presence of four genital pores suggested by Cotteau would result in a most deplorable confusion, so that even if some day a *Schizaster* with four genital pores, otherwise resembling the typical *Sch. Studeri*, should be found in the type locality, it would have to be regarded as not identical with the true *Studeri* and not to afford the reason for changing our conception of the genus *Schizaster* as characterized as having only two genital pores." This statement seems most unreasonable. What Mortensen is in effect saying is that henceforth the type species shall be considered as having two genital pores whether or not this is the truth.

There has been much dispute on the systematic value of the number of genital pores in this group. Duncan & Sladen (1882, p. 330), Currie (1925, p. 73), and Cooke (1942, p. 39) have all considered the number of genital pores as a specific rather than a generic character. Mortensen (1950, p. 216), however, maintains that "the study of recent Schizasterids proves beyond doubt that the number of the genital pores is of primary value for the classification of these forms and that forms with a different number of genital pores cannot rightly belong to the same genus." As evidence, Mortensen states that among recent Schizasterids he has found no variation in the number of genital pores in specimens of the same species. Many instances of such variation have been reported among fossil species. For example, in *Linthia somaliensis* the number of genital pores varies from three to four among specimens which obviously belong to the same species. If two "species" are identical in all respects except in the number of genital pores, it does not seem reasonable to consider them as belonging to separate genera. While the number of genital pores may not be a generic character in the Schizasterids, it is of generic importance in some of the other echinoid groups, such as the family *Brissidae*.

However, as there are many species of *Schizaster*, for the sake of convenience, all species having four genital pores could be referred to a sub-genus *Paraster*.

The type species, *S. studeri*, was designated by the International Congress of Zoology in 1948. This was necessary, for although that name appeared in Agassiz's original description of the genus *Schizaster*, it was then only a *nomen nudum*, as the trivial name was not published with an indication until 1840.

SCHIZASTER AFRICANUS P. de Loriol
Pl. 105, fig. 11

Schizaster africanus P. de Loriol 1863. Mém. Soc. Physique Genève, tome 17, p. 105, 107, pl. 1, fig. 2. Fraas 1867. Aus. dem Orient, p. 135. Lartet 1872. Annales Sci. géologiques, v. 3, art. 5, p. 84. De Loriol 1880. Mém. Soc. Physique Genève, tome 27, p. 117, pl. 8, fig. 13–14. De Loriol 1881. Palaeontographica, bd. 30, p. 49–50, pl. 11, fig. 1. Cotteau 1887. Palaéont. Francaise, tome 1, p. 367. Gauthier 1889a. Echinides Tunisie, p. 93. Gauthier 1889b. Bull. Soc. géol. France, ser. 3, tome 18, p. 143. Cotteau 1894. Palaéont. Francaise, tome 2, p. 697, pl. 371, fig. 1,2, pl. 372, fig. 1. Fourtau 1898. Mém. Inst. égypt (Égypte), tome 3, p. 674. Fourtau 1908. Bull. Inst. égypt, ser. 5, tome 2, p. 141. Fourtau 1913. Cat. Invertébrés Fossiles L'Égypte, Terrains Tertiaires, Échinides Éocènes, p. 58, pl. 6, fig. 3. Stefanini 1919. Boll. Soc. Geologica Italiana, v. 38, p. 49. Airaghi 1939. Annali Museo libico storia naturale, v. 18, p. 277. Zoeke 1952. Bull. Soc. Géol. France, tome 6, 2, p. 49,51,54.

Diagnosis.—Species characterized by large, inflated test with deeply depressed petals and anterior groove. Petals II and IV very flexuous; petals V and I straight, ap-

proximately one-half as long as petals II and IV. Apical system posterior to center, ethmolytic with two genital pores. Peripetalous fasciole very wide passing around extremities of petals. Fasciole curves inward in all interambulacra. Lateral-anal fasciole also present.

Material.—Two specimens, one, C2637, extremely well-preserved although portion of posterior extremity missing; in other specimen, aboral surface almost completely missing, but enough preserved to enable identification.

Remarks.—These specimens are identical in all respects with those described by de Loriol and Fourtau from the Middle Eocene of Egypt.

Distribution.—Karkar series (Middle Eocene) and Middle Eocene of Palestine, Libya (Sirtica), Tunisia, and Egypt.

Localities.—B.27, ϕ129, ϕ139 (Sedgwick Mus. Cat. No. C2637).

Subgenus PARASTER Pomel

Paraster Pomel 1869, Revue des Echinodermes et de leur classification, p. 14.

Type species.—By original designation, *Paraster gibberulus* (L. Agassiz).

Diagnosis.—Similar in all respects to *Schizaster*, but having four genital pores.

SCHIZASTER (PARASTER) HUNTI, n. sp.
Pl. 106, fig. 5–7

Diagnosis.—Species characterized by its great width anteriorly, pointed posterior extremity, and inflated plastron. Petals II and IV much longer than petals V and I; very divergent.

Material.—Four specimens; holotype, C13366, reasonably well-preserved, other three fractured or covered with matrix.

Description.—Holotype 30.0 mm. long, 28.7 mm. wide, 22.6 high. Test very angular with greatest width anterior to center. Front of test blunt, with test tapering back to pointed posterior extremity. Anterior groove distinct, continuing to peristome. Test very inflated with greatest height posterior to apical system; sides of test sloping steeply, with sharp angles at ambitus. Marginal outline angular, asymmetrical, with right anterior side greatly enlarged; plastron very inflated. Apical system slightly anterior, ethmolytic, with four genital pores. Ambulacrum III nonpetaloid with minute pore-pairs; in slight groove near apical system, but more depressed into deep groove where it crosses ambitus and continues to peristome. Petals depressed, straight, narrow, with conjugate pore-pairs and very narrow interporiferous zones. Petals II and IV very divergent, almost twice as long as petals V and I. Interambulacra inflated on aboral surface, especially interambulacrum 5, which forms sharp ridge; plastron very inflated. Peristome anterior, labiate, slightly depressed. Periproct elongated longitudinally, situated in slight posterior truncation high above ambitus, visible from above. Peripetalous fasciole very narrow band passing around extremities of petals, turning sharply inward between petals I and II, and IV and V, but outward between petals II and IV and ambulacrum III, where it passes near ambitus. Lateral-anal fasciole a wider band originating at petals II and IV, passing posteriorly around periproct, forming deep lobe under periproct. Test covered with small perforate, crenulate, irregularly distributed tubercles. On aboral surface, largest tubercles occur along ambulacrum III; on oral surface, on interambulacra 1, 2, 3 and 4 near peristome. Nodes occur on center of each interambulacral plate on aboral surface.

Comparison.—It is with some hesitation that the author refers this species to *Schizaster* (*Paraster*). In having an ethmolytic apical system with four genital pores, a lateral-anal and peripetalous fasciole, an anterior groove, and a longitudinally elongated periproct, this species could be either *Schizaster* (*Paraster*) or *Linthia*. One of the more important differences between the two genera is that in *Linthia* the petals are straight, whereas in *Schizaster* they are curved at their extremities. As the petals are straight in this species, it seems reasonable to refer it to *Linthia*. However, in general appearance it so little resembles the type species *Linthia insignis* (Merian) that it could not be referred to *Linthia*. Its test is very high and steep, as in *Schizaster*, whereas, the test is relatively low in *Linthia*. Its posterior petals, V and I, are much shorter than petals II and IV, a character again of *Schizaster* and not *Linthia*, and its test is very angular. Therefore, the author has

placed this species in *Schizaster*, although it has strong affinities with *Linthia*.

The only species of this genus that this species resembles is *Schizaster insolitus* Fourtau (1909, p. 156) from the Middle Eocene of Egypt. Both species have a similar marginal outline. The Egyptian species has its petals II and IV flexuous and less divergent, a more depressed ambulacrum III, and a higher, more inflated test.

S. hunti is easily distinguished from *S.* (*Paraster*) *beloutchistanensis* from the Karkar series of Somaliland, and the Khirthar series of Kachh. Its petals II and IV are straight instead of flexuous, and its petals V and I are much longer. Furthermore, its apical system is almost central, whereas, it is very eccentric posteriorly in *S. beloutchistanensis*. Its posterior truncation tilts towards the aboral surface making the peristome visible from above, whereas, in *S. beloutchistanensis* the truncation tilts towards the oral surface, with the periproct invisible from above.

S. hunti resembles none of the species of *Schizaster* from India or Europe.

Distribution.—Lower Auradu series (Paleocene) of British Somaliland.

Localities.—ϕ66, σ42, σ61, σ64 (Sedgwick Mus. Cat. Nos. C3063, C3069, C13366, C3076).

SCHIZASTER (PARASTER) sp. cf. S. (P). MESLEI Peron & Gauthier

Pl. 106, fig. 4

Schizaster meslei Peron & Gauthier 1885. Échinides fossiles del L'Algérie, 9e fasc., Étage écoène, p. 62, pl. 4, fig. 4–9.

Diagnosis.—Test of moderate size with greatest width anterior to center. Ambulacrum III deeply depressed aborally into a wide, flat-bottomed depression. This depression only slightly grooved where crossing ambitus, and continuing to peristome. Petals II and IV very flexuous; petals V and I short, straight. Apical system ethmolytic with four genital pores; slightly posterior of center. Periproct high on posterior truncation, slightly visible from above. Peripetalous fasciole widest at extremities of petals. Presumably lateral-anal fasciole present.

Material.—Four specimens, two of which fairly well-preserved although badly weathered. No lateral-anal fasciole visible on specimens, probably destroyed by weathering as that part of test badly preserved where it would occur.

Remarks.—Of all the species of *Schizaster* from Africa and India, these specimens resemble most *Schizaster meslei* from Algeria and Libya. They seem identical with the specimens figured by Airaghi (1939, p. 278) from the Middle Eocene of Libya, although they somewhat differ from the specimens figured by Cotteau. Their test and petals are narrower than in Cotteau's specimen. Probably these specimens belong to the same species as Airaghi's specimens, but more specimens are necessary to be certain.

Comparison.—This species is distinguished from *S.* (*Paraster*) *beloutchistanensis*, also from the Karkar series, by its more blunted posterior truncation which tilts towards the aboral surface, rather than away from it as in *S. beloutchistanensis*. As a result its periproct is visible from above, whereas, it is not in *S. beloutchistanensis*. Ambulacrum III and the petals are much wider in *S.* sp. cf. *S.* (*P.*) *meslei* than in the other species, and the apical system is less eccentric posteriorly.

Schizaster (*Paraster*) *hunti* from the Lower Auradu series is easily distinguished from this species by its straight, narrow petals, almost central apical system, and sharply inflated interambulacrum V. Furthermore, its test is far more inflated.

Distribution.—Karkar series (Middle Eocene) of British Somaliland.

Localities.—ϕ189, ϕ265 (Sedgwick Mus. Cat. Nos. C3198–99).

SCHIZASTER (PARASTER) KARKARENSIS, n. sp.

Pl. 106, fig. 1,2,3

Diagnosis.—Species characterized by fairly wide test with deeply depressed anterior groove, sharply inflated interambulacra, and posteriorly situated apical system, with four genital pores.

Material.—Holotype, C2645, fairly well preserved, although portion of right aboral side broken away. Other three specimens badly fractured, although one of them, C2643, has oral surface intact.

Description.—Holotype 32.4 mm. long, 29.3 mm. wide, 22.3 mm. high. Greatest width near center, or slightly anterior of

center of test; greatest height posterior of posteriorly eccentric apical system. Ambulacrum III deeply depressed crossing ambitus, continuing to peristome. Petals deeply depressed, with interambulacra inflated. Apical system posteriorly eccentric; ethmolytic with four genital pores. Ambulacrum III in broad, deeply depressed, flat-bottomed groove; greatest width midway between apical system and ambitus. Pore-pairs non-conjugate, slightly oblique, occurring at base of nearly vertical wall of groove. Outer pore larger than inner. Petals deeply depressed, with conjugate, transversely elongated pore-pairs. Interporiferous areas narrower than poriferous zones. Petals II and IV flexuous, curving anteriorly at their extremities; petals V and I straight, nearly half as long as petals II and IV. Orally, ambulacra V and I very narrow. Aborally, interambulacra very inflated with steep sides. Interambulacra 2 and 3, more inflated than interambulacra 4 and 1. Orally, plastron wide with wide labrum. Peristome very eccentric anteriorly, much wider than high. Periproct high on posterior truncation, elongated longitudinally. Only portions of peripetalous and lateral-anal fascioles visible. Peripetalous fasciole a wide band passing around extremities of petals, curving sharply towards apical system in interambulacra 4 and 1. Lateral-anal fasciole a narrow band with only short portion preserved on these specimens. Test covered with small, perforate tubercles, largest on oral surface, particularly on interambulacra 2 and 3; plastron densely covered.

Comparison.—This species is very similar to *Linthia cotteaui* Tournouer from the Middle Eocene of France. The general shape and petal arrangement of both species are very similar. In *S. karkarensis*, petals II and IV are slightly more flexuous, and are wider at their extremities. Also the interambulacra are more sharply inflated, and the peristome smaller and lower.

Schizaster karkarensis is also somewhat similar to *Schizaster libycus* Fourtau (1909, p. 157) from the Middle Eocene of Egypt. Both species are similar in general appearance, but *S. karkarensis* has a wider and lower test, a more pronounced anterior groove, petals II and IV more divergent, and four instead of three genital pores.

Among the Somaliland species of *Schizaster*, this species most resembles *S.* sp. cf. *S.* (*P.*) *meslei*. However, petals II and IV, in *S. karkarensis*, are narrower, less flexuous, and more divergent. Its interambulacra are more inflated with sharper ridges.

This species does not resemble any of the species of *Schizaster* from India.

Distribution.—Karkar series (Middle Eocene) of British Somaliland.

Locality.—B.5 (Sedgwick Mus. Cat. Nos. C2643, C2647–48).

SCHIZASTER (PARASTER) BELOUTCHISTANENSIS (D'Archiac)
Pl. 106, fig. 8,9,10

Hemiaster beloutchistanensis D'Archiac 1850. Histoire des progrès de la Géologie, tome 3, p. 252.

Schizaster beloutchistanensis D'Archiac & Haime 1853. Description des Animaux Fossiles du Groupe Nummulitique de L'Inde, p. 221–222, pl. 15, fig. 9a,b. Duncan & Sladen 1884. Paleontologia Indica, ser. 14, v. 1, p. 224.

Schizaster Delorenzoi Checchia-Rispoli 1950. Boll. Ufficio geol. Italia, v. 70, p. 35–36, pl. 2, fig. 5.

Diagnosis.—Species characterized by shape, with greatest width anterior to center, and pointed posterior extremity. Apical system eccentric posteriorly, ethmolytic with four genital pores. Ambulacrum III in deep groove aborally, but only slightly depressed crossing ambitus and continuing to peristome. Petals II and IV flexuous, long; petals V and I straight, short. Posterior truncation oblique, tilting away from aboral surface with periproct not visible from above. Peripetalous fasciole curves inward in all interambulacra. Lateral-anal fasciole present.

Material.—Three well preserved specimens.

Remarks.—These specimens are identical with both *Schizaster beloutchistanesis* from the Nummulitic series of Kachh, and with Checchia-Rispoli's *Schizaster delorenzoi* from the Karkar series of Italian Somaliland. Both species have their posterior extremities obliquely truncated, identical petals, posteriorly eccentric apical systems with four genital pores, and similar fasciole tracks, with the peripetalous fasciole curving anteriorly where it crosses ambulacrum III. Orally, the tuberculation of the wide plastron is inditinguishable, and both have nar-

row ambulacra zones. In no feature do they differ and, therefore, *Schizaster delorenzoi* must be considered synonymous.

Distribution.—Karkar series (Middle Eocene) of British and Italian Somaliland and Middle Eocene of Kachh.

Localities.—ϕ140, σ202, Burud (Sedgwick Mus. Cat. No. C13367).

SCHIZASTER (PARASTER) DUROENSIS, n. sp.
Pl. 106, fig. 11,12,13,14

Diagnosis.—Species characterized by low heart-shaped test with pointed posterior extremity, distinctly grooved anterior margin. Petals II and IV narrow, much longer than petals V and I, straight in small specimens, slightly flexuous in large. Posterior extremity obliquely truncated with periproct not visible from above.

Material.—Seventy-four specimens mostly iron-stained, partly silicified, badly weathered, with a few well preserved specimens showing features of species. Holotype, C13368, complete, although badly weathered, shows shape of test, and petal arrangement. Paratype, C3085, shows fascioles.

Description.—Dimensions (mm.) of four specimens:

Specimen	Length	Width	Height
C3091	33.4	30.5	22.0
C3086	37.5	32.8	22.1
C3145	39.0	35.3	23.0
C3081	46.5	40.1	27.1

Test heart-shaped with greatest width anterior to center. Anterior margin rounded, posterior margin pointed. Greatest height midway between apical system and posterior margin. Interambulacrum 5 very sharply inflated. Posterior margin truncated obliquely with periproct not visible from above. Anterior groove deep, petals depressed. Apical system situated slightly posterior of center; slightly depressed, ethymolytic with four genital pores. Ambulacrum III nonpetaloid, situated in wide, depressed groove which deepens as it continues to peristome. Pore-pairs small with obliquely situated pores; inner pore being more anterior than outer. Plates of this ambulacrum narrow, curving slightly towards apical system near median sutures. Pores not conjugate, but separated by transverse ridge. Petals II and IV long, almost extending to ambitus, almost straight in small specimens, but flexuous in large specimens. Petals V and I short, straight, being almost one-half as long as petals II and IV. Both pairs of petals depressed with conjugate pores with narrow interporiferous zones. Aborally, interambulacra 2, 3, 4, and 1 only slightly inflated. Interambulacrum 5 highly inflated into sharp ridge. Orally, labrum large, broad, mushroom-shaped with pronounced reflected lip; sternals long, narrow. Peristome very eccentric anteriorly, very wide, low crescent shaped. Periproct elongated longitudinally, very narrow, occurring high on slightly oblique posterior truncation, not visible from above on most of specimens. Test covered with small, perforate tubercles, largest along anterior groove and around peristome. Peripetalous fasciole a very narrow band passing around extremities of petals, widest where it passes around petals II and IV; curving very sharply inward just posterior of petals II and IV, and passing posteriorly well above ambitus until near periproct where it drops down into trough under periproct.

Remarks.—The author has referred this species to *Schizaster* although it does have affinities with *Linthia*. Its deep anterior groove, slightly flexuous petals II and IV, and short petals V and I are typical of *Schizaster;* its low test is a feature of *Linthia*. It seems to be rather intermediate between the two, for while petals II and IV are flexuous on the large specimens, they are straight on the small.

Comparison.—This species resembles none of the species of *Schizaster* from the Lower Tertiary of India and Egypt. The only species of *Schizaster* it does resemble, and that slightly, is *Schizaster* (*Paraster*) *tournoueri* Cotteau (1887, p. 301) from the Middle Eocene of France. Both species are heart-shaped and have their apical systems slightly posterior to the center. *Schizaster duroensis* has a much lower test, a more pointed and more obliquely truncated posterior extremity, and a more sharply inflated interambulacrum 5. Its petals are much narrower and straighter, and its fascioles more angular.

S. duroensis resembles none of the other species of *Schizaster* from British Somaliland. Its broad, depressed test distinguishes it from all of them. It does slightly resemble

Opissaster auraduensis also from the Lower Auradu series. Both species have depressed petals and depressed tests. The test in *O. auraduensis* is not heart-shaped, as its greatest width is central, not anterior of the center, and its posterior margin is truncated and not pointed. Petals II and IV of *O. auraduensis* are straight; they are flexuous in *S. duroensis*. *O. auraduensis* has no lateral-anal fasciole.

Distribution.—Lower Auradu series (Paleocene) of British Somaliland.

Localities.—ϕ122, σ188 (Sedgwick Mus. Cat. Nos. C3081–92, C3145, C13368).

Genus LINTHIA Desor

Linthia Desor 1853. Verh. Schweiz. Naturf. Gesell., band 38, p. 278.

Type species.—*Linthia insignis* (Merian), by subsequent designation of Desor 1858, p. 395.

Diagnosis.—Test of variable size, usually low, anteriorly grooved, posteriorly truncated. Apical system anteriorly eccentric, ethmolytic with four genital pores. Petals depressed, straight, with petals II and IV longer than V and I. Both peripetalous and lateral-anal fasciole present.

Remarks.—*Linthia* is very similar to *Lutetiaster*. The latter was erected for the species of *Linthia* that have the periproct elongated transversely instead of longitudinally. They are indistinguishable otherwise.

Some species of *Linthia* are very similar to species of *Schizaster*. Species of both genera have depressed petals, an anterior groove, an ethmolytic apical system with four genital pores, and a peripetalous and lateral-anal fasciole. However, the anterior groove is usually deeper, petals II and IV more flexuous, and petals V and I shorter in *Schizaster*. Furthermore, in *Schizaster* the test is usually higher and more angular. Cooke (1942, p. 41), considers them so similar that he refers to *Linthia* as a subgenus of *Schizaster*.

LINTHIA SOMALIENSIS Currie

Text-fig. 16; Pl. 106, fig. 15,16

Linthia somaliensis Currie. 1927. Trans. Royal Soc. Edinburgh, v. 55, p. 432–435, pl. fig. 2,3.
Linthia arabica Clegg 1933. Paleontologica Indica, v. 22, p. 16–17, pl. 2, fig. 1–2.
Linthia Mortenseni Checchia-Rispoli 1950. Boll. Ufficio geol. Italia, v. 70, p. 36–38, pl. 1, fig. 4.
Linthia Mortenseni var. *depressa* Checchia-Rispoli. Boll. Uffico geol. Italia, v. 70, p. 38, pl. 1, fig. 5.

Diagnosis.—Test moderately large, with slight anterior groove. Greatest width anterior to center, greatest height posterior. Apical system central to slightly anterior of center, ethmolytic with three or four genital pores. Petals wide, slightly depressed on small specimens but deeply depressed on large. Petals II and IV almost straight, very divergent, longer than petals V and I. Pores in ambulacra on oral surface very large particularly near peristome. Periproct elongated longitudinally, occurring high on slight posterior truncation. Both peripetalous and lateral-anal fasciole present.

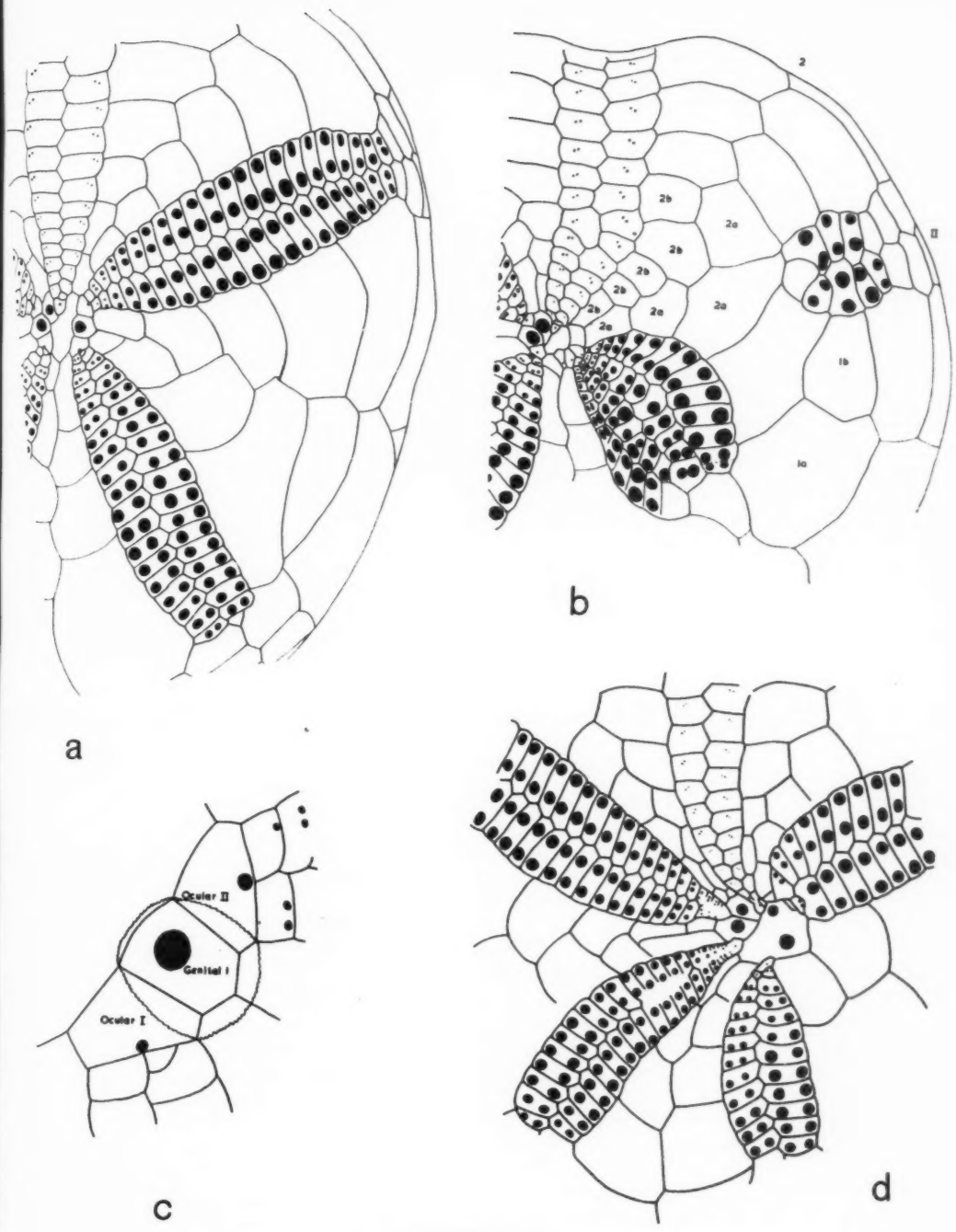
Material.—Most of 133 specimens extremely well preserved, being weathered in manner that plate sutures remarkably clear.

Remarks.—Clegg described a new species, *Linthia arabica* from the Lower Eocene of Oman, Arabia which is identical in all respects with this species and must be considered synonymous. Clegg compares his species to this species and states that they differ, but he fails to point out any differences. Clegg's specimens are not available for study, but it is evident from a study of his description and figures, that the two species are the same.

Evidently, Checchia-Rispoli has not seen Currie's paper, as his *Linthia mortenseni* and variety *depressa* are also synonymous with *L. somaliensis*. His specimens were collected in Italian Somaliland (Migiurtinia) from the Karkar series. In the Sedgwick Museum Collection, the larger specimens, because of their deeper petals and more angular outline, appear to be slightly different from the smaller ones. Checchia-Rispoli's *L. mortenseni* refers to the larger specimens, his variety *depressa* to the smaller.

Sixty-eight of the specimens have visible apical systems. As many as ten of these have only three genital pores. In every case (text-fig. 16a) the unpierced genital is genital 2. Five of the specimens show genitals 2 and 5 extremely well, but no suture is discernible between them. In four of them, genital 3 is in contact with ocular V, isolating genital 4 from genital 2.

Abnormalities.—One specimen, C2944,



TEXT-FIG. *16*

Linthia somaliensis Currie. a. Aboral view of part of normal specimen C2967. ×3. b. Aboral view of part of abnormal specimen C2944 showing the double petal and the remnant of petal II. ×3. c. A hypothetical drawing showing the region (enclosed by a wavy line) in the apical system which, if destroyed in a young *Linthia somaliensis*, might produce the abnormality figured in b. d. Aboral view of abnormal specimen C13371 showing the eccentric apical system with twisted petals; petals I and II also being quite short. In the drawing, petals I and V are complete, but only part of petals II and V are shown. ×3.

from locality A.26, has a remarkable and rare abnormality. This unusual echinoid has five oculars, three or possibly four genitals, five ambulacra, five interambulacra orally but only four aborally. This tetramerous varient belongs to either Jackson's (1927, p. 516–528) group 10h or 10L. As only two regular and no irregular echinoids have ever been described in these two groups, this specimen is of much interest.

The plates of the oral and ambital region are normal; the ambital part of petal II, consisting of four pairs of plates bearing pore-pairs, is present in normal position between interambulacra 1 and 2 (text-fig. 16b, fig. 16a is of a normal specimen for comparison). Aborally, interambulacrum 1 ceases and petals I and II are combined into one double ambulacrum. Plates from interambulacrum 2 fill the gap between the double petal and the short isolated portion of petal II. Ambulacrum III is slightly twisted. What are assumed to be oculars I and II are in contact, and genital 1 is either missing or among several indeterminable plates to the left of ocular I.

This abnormality was probably caused by some injury to the right and left oral border of ocular I and II respectively. It is in this area that new interambulacral plates are produced, and any injury here (Jackson 1927, p. 528) would have had an immediate effect on the production of new interambulacral plates. This injury also either displaced or destroyed genital 1, and oculars I and II moved into the gap and came into contact (text-fig. 16c showing area affected).

Another specimen of interest (text-fig. 16d) is one in which the apical system is eccentric towards the right, with the petals twisted. Orally and well above the ambitus, the plate arrangement is normal with the extremities of the petals unaffected (in text-fig. 16d all of petals V and I are drawn, but not all of II and IV). However, the portions of the petals and ambulacrum III near the apical system are very misshapen. Ambulacrum III and petal V swing very sharply towards the right of the test. Petal IV is stretched and petals I and II are quite short. There are only 11 and 13 pore-pairs respectively in petals II and I as compared to 21 and 19 in IV and V. The oculars of these two reduced petals are very small. This arrangement was probably due, again, to some injury to the echinoid when it was young.

Distribution.—This species has the widest vertical distribution of any of the Eocene echinoids in the collection. It occurs from the upper horizons in the Auradu series (Lower Eocene) up into the higher horizons of the Karkar series (Middle Eocene) in British Somaliland. It has also been reported from Italian Somaliland and Arabia.

Localities.—Lower Eocene—Upper Auradu series—A.26, B.33, ϕ36, ϕ39, σ117, σ193, σ64. Middle Eocene-Karkar series —ϕ129. Sedgwick Mus. Cat. Nos. C2607–11, C2936–67, C2969–77, C3065, C3207–8, C13369–71.

LINTHIA CAVERNOSA P. de Loriol

Text-fig. 17; Pl. 106, fig. 17,18,19

Linthia cavernosa de Loriol 1880. Mém. Soc. Physique Genève, tome 27, p. 111–113, pl. 8, fig. 8–10. de Loriol. 1881. Palaeontographica, bd. 30. p. 41, pl. 8, fig. 7.

Linthia cavernosa Cotteau 1886. Palaéont. Francaise Éocène, tome 1, p. 265.

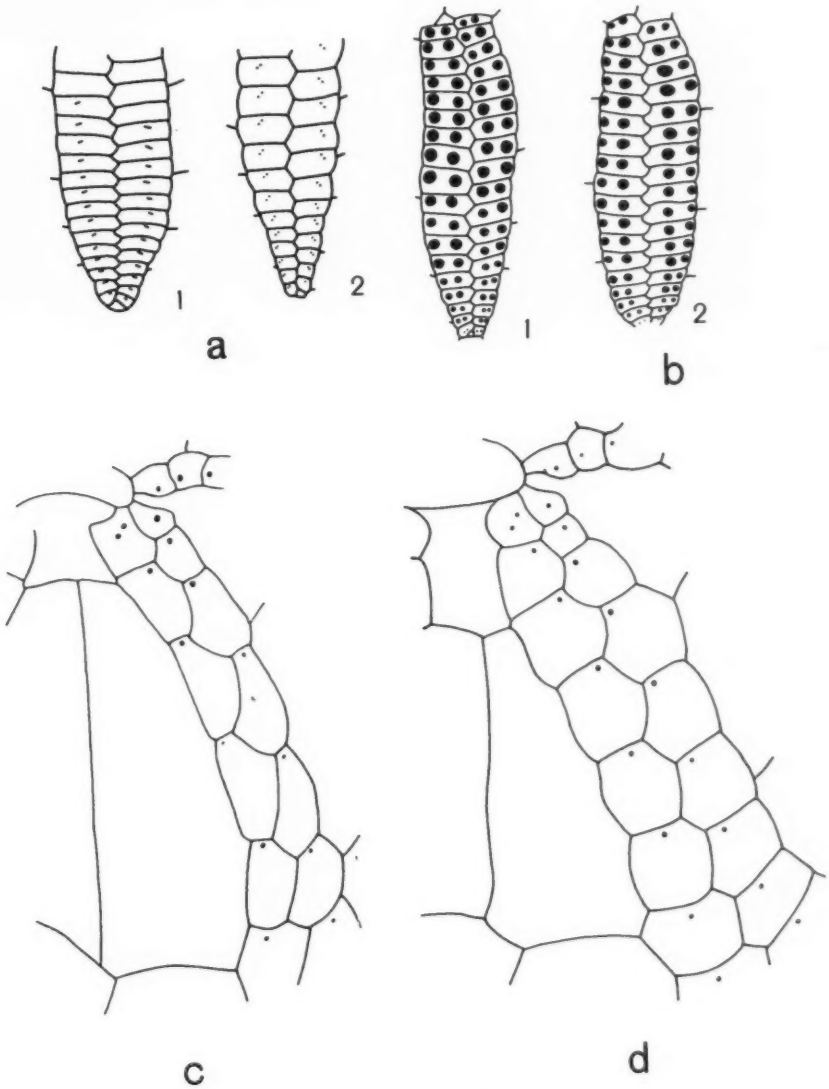
Linthia cavernosa Fourtau 1898. Mém. Inst. égypt (Égypte), tome 3, p. 670.

Linthia cavernosa Gregory 1898. Geol. Mag. D. 4, v. 5, p. 159.—Fourtau 1900b. Notes sur les Échinides fossiles de l'Égypte, p. 39. Fourtau 1905. Bull. Inst. égypt, tome 5, ser. 4, p. 139. Fourtau 1909. Mém. Inst. égypt (Égypte), tome 6, p. 148. Fourtau 1913. Cat. Invertébrés Fossiles l'Égypte, Terrains Tertiaires, Échinides Éocènes, p. 51–52. Cuvillier 1930. Mém. Inst. égypt (Égypte), tome 16, p. 147.

Linthia Aschersoni de Loriol 1881. Palaeontographica, bd 30, p. 37–39, pl. 9, fig. 1–4. Cotteau 1886. Palaéont. Francaise Eocène, tome 1, p. 266. Fourtau 1898. Mém. Inst. égypt (Égypte), p. 671. Gregory 1898. Geol. Mag. D. 4, v. 5, p. 159.

Diagnosis.—Test moderately large, with slight anterior groove. Greatest width anterior of center; greatest height posterior. Apical system central to slightly anterior, ethmolytic with four genital pores. Petals long, depressed, Petals II and IV straight, very divergent, longer than petals V and I. Interporiferous zones quite wide. Periproct elongated longitudinally, occurring high on slight posterior truncation. Both peripetalous and lateral-anal fasciole present. Orally, ambulacra V and I narrow.

Remarks.—Fourtau (1900a, p. 89) exam-



TEXT-FIG. 17

Linthia cavernosa and *L. somaliensis*. a. View of ambulacrum III of *L. cavernosa* (1), C2638, and *L. somaliensis*, (2) C2967, showing the wider and lower ambulacral plates in *L. cavernosa*. ×3. b. View of petal I of *Linthia cavernosa* (2) C2638, and *L. somaliensis*, (1) C2967, showing the greater width of the interporiferous zones in *L. cavernosa*. ×3. c–d. View of the plastron and of ambulacrum V of *L. cavernosa* (C) C2638, and *L. somaliensis* (d) C2951, showing the narrower ambulacrum zone in *L. cavernosa*. ×3.

ined large numbers of specimens of *Linthia cavernosa* and *Linthia aschersoni* and decided that they should be united into one species. The author examined some specimens in the British Museum of Natural History referred to both species and was unable to see any difference between the two.

Material.—One specimen, C2638, although complete, weathered with pore-pairs enlarged.

Discussion.—This specimen is similar in most respects to *Linthia cavernosa* described from the Lower and Middle Eocene of Egypt. This specimen has been compared with specimens from Egypt, in the British Museum of Natural History. They are similar in petal arrangement, having petals of the same shape and length. The apical systems are almost identical, with the genital pores widely separated. In the Somaliland specimen, the sides are steeper, the anterior margin narrower, and the edge of the petals are sharply depressed, whereas, in the Egyptian specimens the interambulacra pass gently into the petals. These slight differences do not seem to warrant distinguishing this specimen as a separate species, especially as only one specimen is available and the consistency, therefore, of these differences is not known.

Comparison.—This species resembles *Linthia somaliensis* in its shape and general petal arrangement. In *Linthia cavernosa* the anterior groove is wider with wider and lower plates (text-fig. 17a), the interporiferous zones of the petals are wider (text-fig. 17b), and finally ambulacra V and I on the oral surface are much narrower (text-fig. 17c,d).

Lambert and Thiéry (1925, p. 521) refer *Linthia cavernosa* to *Lutetiaster*. This is a mistake, but they probably did so because one of de Loriol's figures (1881, pl. 8, fig. 7) gives the impression that the periproct is transversely elongated. The figure of *Linthia aschersoni* (1881, pl. 9, fig. 1c) clearly shows a longitudinally elongated periproct. The specimens examined in the British Museum of Natural History also had longitudinally elongated periprocts.

Distribution.—Karkar series (Middle Eocene) of British Somaliland, and Eocene of Egypt.

Locality.—B.56 (Sedgwick Mus. Cat. No. C2638).

Genus LUTETIASTER Lambert

Lutetiaster Lambert 1920. Mém. Soc. acad. Aube, tome 84, p. 27.

Type species.—*Lutetiaster subglobosus* (Lamarck), designated by Lambert, 1920, p. 169.

Diagnosis.—Genus similar to *Linthia* in all respects except periproct transversely elongated.

LUTETIASTER MACCAGNOI Checchia-Rispoli

Lutetiaster maccagnoi Checchia-Rispoli 1950 Boll. Ufficio geol. Italia, v. 70, p. 38–39, pl. 1, fig. 3.

Diagnosis.—Test moderately large, inflated, with greatest width central, greatest height posterior to center. Apical system slightly anterior to center, ethmolytic with four genital pores. Ambulacrum III very depressed into flat-bottomed groove continuing over ambitus to peristome. Petals long, deeply depressed. Petals II and IV straight, slightly flexuous; longer than petals V and I. Periproct transversely elongated. Peripetalous fasciole curves very sharply inwards in interambulacra 1 and 4; lateral-anal fasciole present.

Material.—Three fragments and one complete specimen, C2641, identical with those described by Checchia-Rispoli from Karkar series of Italian Somaliland (Migiurtinia). In specimen C2641, interambulacral columns 2b and 3a isolated from ocular III, indicating that echinoid had ceased production of new plates for these two areas.

Comparison.—This species very closely resembles the type species, *Lutetiaster subglobosus* (Lamarck) from the Eocene of France and Carinthia. It differs only in having deeper petals, a deeper anterior groove, and a slightly narrower test.

L. maccagnoi somewhat resembles *Opissaster farquharsoni* from the Upper Auradu series. Both species have deeply depressed petals, and inflated tests, with the greatest height posterior to the center. Also, in both species the apical system is ethmolytic with four genital pores. However, the test of *O. farquharsoni* is larger with less inflated inter-

ambulacra. Its apical system is more eccentric anteriorly, and less depressed, and its periproct is elongated longitudinally instead of transversely. There is no lateral-anal fasciole in *O. farquharsoni*.

Distribution.—Karkar series (Middle Eocene) of British and Italian Somaliland.

Locality.—B.5 (Sedgwick Mus. Cat. Nos. C2642, C2644, C2646, C2641.

Family BRISSIDAE Gray, emend. Mortensen

ARCAECHINUS, n. gen.

Type species.—*Arcaechinus auraduensis*, n. sp., from the Upper Auradu series (Lower Eocene) of British Somaliland.

Diganosis.—Test elongate with greatest width anterior to center. Apical system ethmolytic with three genital pores, genital 2 being unpierced. Ambulacrum III, non-petaloid, in very slight groove. Petals slightly depressed; petals II and IV straight, short, petals V and I long, slightly divergent at extremities. Periproct elongated longitudinally, situated high on slight posterior truncation. Labrum prominent with long posterior extension. Sternum narrow with straight, wide ambulacral tracts on either side. Both peripetalous and sub-anal fasciole present.

Comparison.—Being amphisternous, and possessing both a peripetalous and subanal fasciole, this genus belongs to the family Brissidae. The presence of only three genital pores seems to be an important systematic feature in this group. In the Brissidae, there are only two genera with three genital pores, *Cyclaster* and *Anabrissus*. *Cyclaster* is easily distinguished from *Arcaechinus* by having a rounded-oval marginal outline, short petals, and an ethmophractic apical system. *Anabrissus* differs by having a rudimentary peripetalous fasciole, a short labrum, a broad sternum, and genital 3 unpierced instead of genital 2, as in *Arcaechinus*.

Ignoring the number of genital pores, this genus bears closest resemblance to *Brissus*. The two genera are alike in their general shape, in having anterior, ethmolytic apical systems, and similar petal arrangement, with subequal conjugate pores. Both have an angular peripetalous fasciole, and a reniform subanal fasciole. Orally, *Brissus* is quite distinct. It has a short labrum, and a large, broad sternum, with narrow adjacent ambulacra, whereas, in *Arcaechinus* the labrum is long, and the sternum long and narrow, with wide adjacent ambulacra.

ARCAECHINUS AURADUENSIS, n. sp.
Text-fig. 18; Pl. 107, fig. 6,7,8

Material.—Thirty specimens and fragments of specimens. Holotype, C2996, complete, uncrushed; paratype C2986 larger, showing shape of test and arrangement of petals in mature specimen, paratype C3002 exhibiting arrangement of plates on oral side, paratype C2987, because of weathering, showing distinct plate sutures on aboral surface.

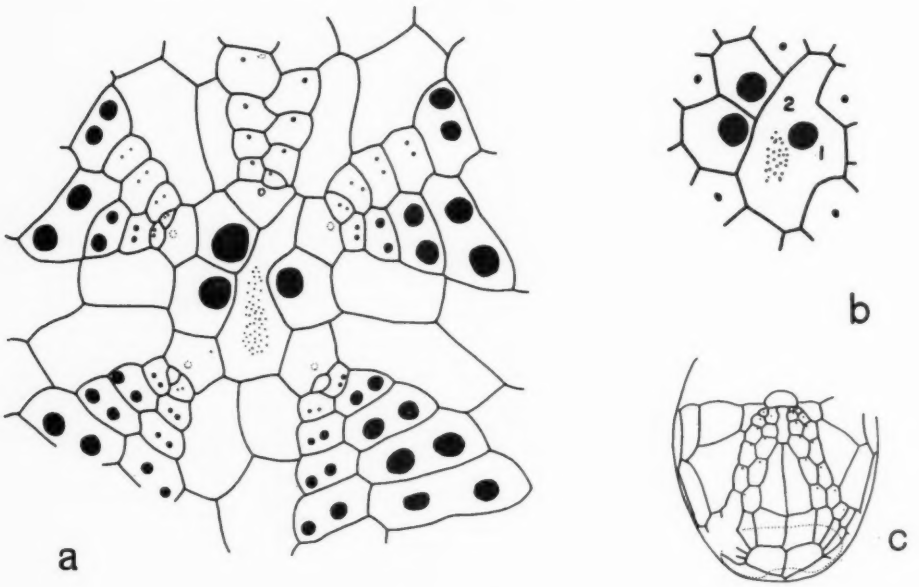
Description.—Dimensions and number of pore-pairs in petals of six specimens are given in Table 8. Test coffin-shaped, with greatest width anterior to apical system, greatest height midway to two-thirds of distance from apical system to posterior extremity. Marginal outline blunted anteriorly and posteriorly. Ambulacrum III in slight groove, but petals only slightly depressed. Paired ambulacra on oral side not depressed, but flush with test. Apical system (text-fig. 18a) eccentric anteriorly, slightly depressed, with only three genital pores as genital 2 not pierced in any of the thirteen specimens having visible apical systems. Apical system ethmolytic with madreporite extending posteriorly, separating posterior genitals and oculars. Several oculars of two

TABLE 8.—DIMENSIONS AND NUMBER OF PORE-PAIRS IN *Arcaechinus auraduensis*

Specimen	Length	Width	Number of pore-pairs		
			Height	Petal II or IV	V or I
C2998	33.7	26.7	19.9	25	27
C2994	38.0	28.6	—	25	29
C2996	43.6	33.3	24.5	25	29
C2987	52.6	39.8	—	28	34
C2986	55.8	41.6	27.7	28	35
C2988	57.8	42.5	28.6	27	35

of largest specimens, C2986 and C2988, isolated from adjacent interambulacral columns indicating production of interambulacral plates ceased at maturity in this species. In paratype C2987 (text-fig. 18a) interambulacral column 2 uniserial for length of one plate. In specimen C2998 (text-fig. 18b) apical system very well preserved with sutures quite clear, but no suture visible between genitals 1 and 2. Ambulacrum III flush with test near apical system, but depressed in slight groove crossing ambitus, groove continues to peristome. Pore-pairs in ambulacrum III minute, oblique. Petals II and IV slightly depressed, broad, straight, extending almost to ambitus. Number of pore-pairs in these petals varies from 25 in smaller specimens to 28 in larger. Petals V and I also slightly depressed, broad, but longer, with from 27 to 35 pore-pairs in a column. These petals confluent for approximately one-half length, but divergent at extremities. In both pairs of petals, interporiferous zones narrower than poriferous, with greatest width near mid-length of petals. Pore-pairs conjugate with inner pore round, outer pore slightly elongated transversely. Pore-pairs separated by ridge bearing single line of small milaries. Near apical system ambulacral plates and pore-pairs greatly reduced in columns Ia, IIb, IVa, Vb (text-fig. 18a).

Interambulacra.—Labrum prominent (text-fig. 18c), with slight lip, posterior extension very long, reaching to third adjoining ambulacral plate. Labrum about one-half as long as sternum. Sternum very narrow with slight median keel terminating in node at its posterior extremity. Ambulacral tracts on either side straight, granulated, wide. Periproct elongated longitudinally, situated high on slight, vertical posterior truncation. Peristome anteriorly eccentric, more so than apical system, slightly sunken, transverse, with slight lip. Both subanal and peripetalous fasciole present. Peri-



TEXT-FIG. *18*

Arcaechinus auraduensis, n. sp. a. View of the apical area of paratype C2987 showing the presence of three genital pores in the ethmolytic apical system, and the reduced size of the pore-pairs near the apical system. ×10. b. View of the apical system of specimen C2998 in which the suture between genitals 1 and 2 is not visible ×10. c. View of the plastron of paratype C3002 showing the plate arrangement. The subanal fasciole is indicated by a dotted line. ×1.

petalous fasciole a narrow symmetrical band passing close to extremities of petals, curving slightly inward in interambulacra 1 and 4, outward in interambulacrum 5, where in some specimens occurs an outward extension of this fasciole. In interambulacra 2 and 3, fasciole sometimes curves sharply inward and then outward just beyond petals. Subanal fasciole very large, reniform, with deep trough below periproct; no anal branches. Tubercles crenulate, perforate, surrounded by scrobicular ring of granules. Smaller granules occur in spaces between these rings. Tubercles occur inside and outside peripetalous fasciole, with few sometimes occurring on interporiferous zones. None occur on ambulacra V and I adjacent to sternum, but occur on ambulacral plates continuing beyond petals II and IV, and, although reduced in size, on ambulacrum III. Single line of large granules border fascioles.

Distribution.—Upper Auradu series (Lower Eocene) of British Somaliland.

Localities.—A.26, ϕ36 (Sedgwick Mus. Cat. Nos. C2986–C3006).

Genus MIGLIORINIA Checchia-Rispoli

Migliorinia Checchia-Rispoli 1942. Rend. Accad. Italia, f. 6, p. 305.

Type species.—By original designation, *Migliorinia migiurtina* Checchia-Rispoli.

Diagnosis.—Test small, low, with slight, broad, anterior groove. Petals broad, flush to slightly depressed, of equal length, with very narrow interporiferous zones. Peripetalous and cordiform subanal fasciole present; no concentration of tubercles within area circumscribed by peripetalous fasciole. Apical system small, anteriorly eccentric, ethmolytic with four genital pores. Labrum long, narrow, periproct visible from above.

Remarks.—This genus is very similar to *Eupatagus*. In fact the type species is almost indistinguishable from small specimens of *Eupatagus dainellii*, a species occurring at the same horizon. In only two characters do they differ. In *Migliorinia migiurtina* the interporiferous zones are narrower, and there are no large tubercles within the area circumscribed by the peripetalous fasciole. It is in these features that the genus *Migliorinia* is distinguished from the genus *Eupatagus*.

While the differences between *Migliorinia* and *Eupatagus* are slight, these two characters are consistent within the type species and may be reliable generic distinctions. Therefore, for the time being, it seems advisible to maintain Checchia-Rispoli's genus.

Fourtau (1904, p. 606) erected a separate genus *Heterospatangus* for species of *Eupatagus* in which the large aboral tubercles are not confined within the peripetalous fasciole. As pointed out by Mortensen (1951, p. 461), in Fourtau's type species *Heterospatangus lefebvrei* (de Loriol) the tubercles are sometimes confined as shown in some of de Loriol's figures (1881, pl. 11, fig. 2,3). As a result, his type species is indistinguishable from *Eupatagus*. One of the species he referred to *Heterospatangus, H. moelehensis* Fourtau (1909, p. 166) from the Middle Eocene of Egypt, is clearly not a *Eupatagus*. Not only does it lack large aboral tubercles within the area circumscribed by the peripetalous fasciole, but its interporiferous zones are narrower than is usual for *Eupatagus*. This species should be referred to *Migliorinia*.

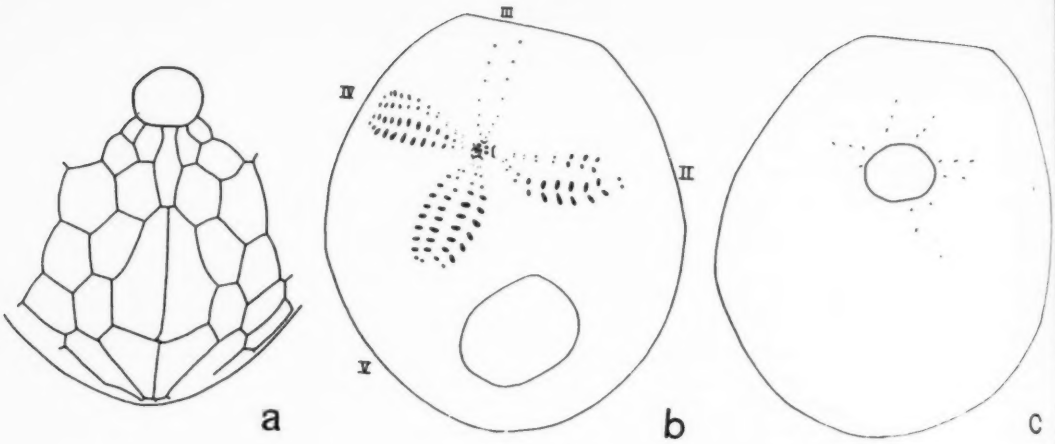
Mortensen, who does not compare this genus with *Eupatagus*, considers the central position of the peristome in *Migliorinia* as a character which distinguishes this genus from the other genera of the family Brissidae. However, in many species of *Eupatagus* the peristome is as centrally located.

MIGLIORINIA MIGIURTINA Checchia-Rispoli
Text-fig. 19,20; Pl. 107, fig. 1–5

Migliorinia migiurtina Checchia-Rispoli 1942. Rend. Accad. Italia, fas. 6, ser. 7, v. 3: (1941), p. 305–307, text-fig. 1–3, pl. fig. 1–10. Mortensen 1951. A Monograph of the Echinoidea, v. 5, Spatangoida, 2, Copenhagen, p. 456, text-fig. 228.

Material.—274 specimens, poorly preserved, many weathered, fractured, or crushed.

Remarks.—There is little that can be added to Checchia-Rispoli's excellent description and illustrations of this species. However, the peristome is not anteriorly pointed as in his text-figure 1, a drawing probably based on the specimen of his plate



TEXT-FIG. *19*

Migliorinia migiurtina Checchia-Rispoli. a. Oral view of specimen C2821 showing the plastron with its long narrow labrum and a short sternum. ×1.5
Abnormality. b. Aboral view of specimen C2918 showing distorted test with enlarged, oblique periproct, eccentric apical system, and only three petals. c. Oral view showing the presence of only four ambulacra at the peristome. ×3.

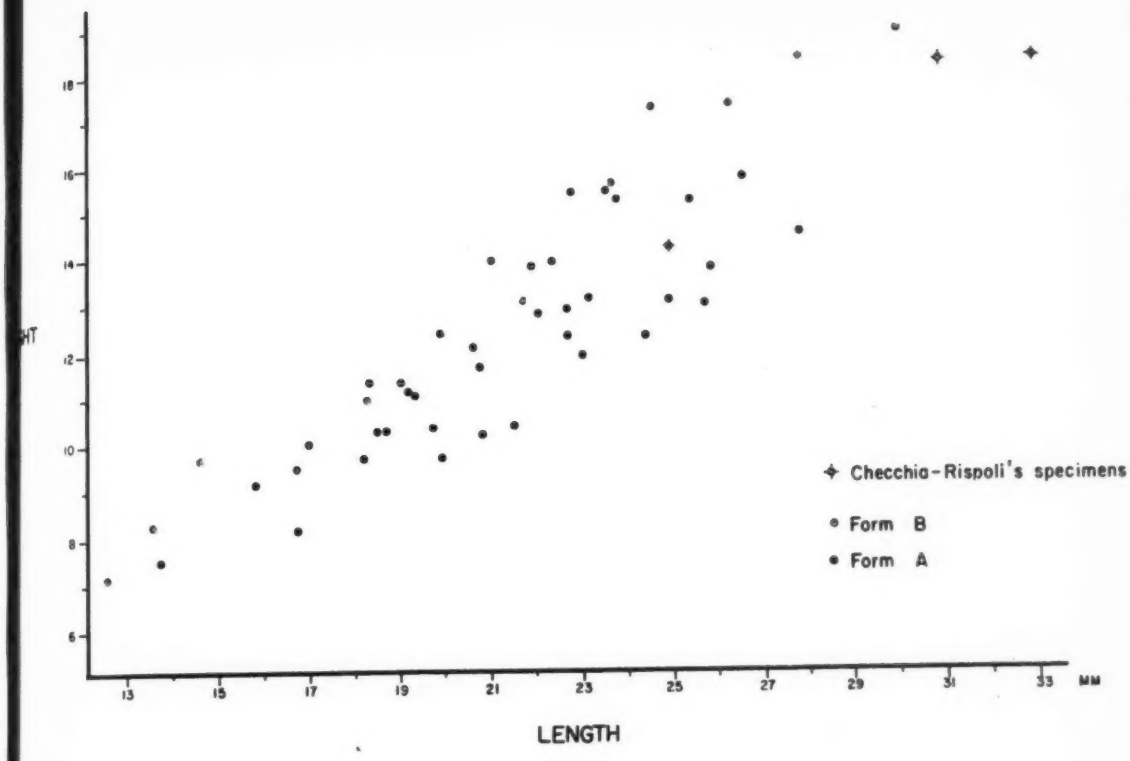
figure 6. Apparently, this specimen had been fractured in the peristomal region, for in his other specimen, plate figure 9, in which the peristome is visible, and in all the specimens of this collection, the anterior margin of the peristome is not angular but curved. Checchia-Rispoli also described the labrum as being short. While it is narrow, it is not short but very long for a member of the family Brissidae (text-fig. 19a). The outline of the labrum is visible in one of Checchia-Rispoli's figured specimens in his plate figure 9.

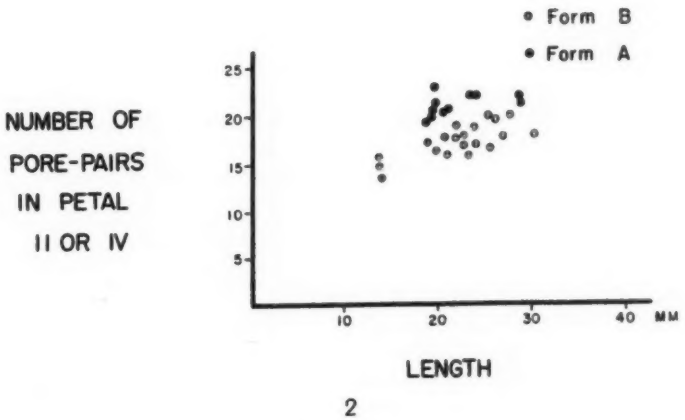
The specimens in the collection can be divided into two groups according to the shape of the test. Those collected by Barrington Brown from eastern British Somaliland and by the Somaliland Petroleum Company from the upper part of the section at Burud represent what, for convenience, can be called Form B. All the other specimens are included in Form A. The two forms never occur in the same horizon.

The specimens of Form B have a higher test, steeper sloping sides, flatter aboral and more rounded oral surfaces than those of Form A. This difference in the height of the test between the two groups is clearly shown in text-fig. 20-1 in which the height of many of the specimens is plotted in relation to the length. The points that represent Form B occur in a path distinct from those of Form A. The specimens of Form B have fewer pore-pairs than Form A. This difference is illustrated in text-fig. 20-2 in which the number of pore-pairs in petal II or IV is plotted against the length of the specimens. Again the paths of the points are different.

The specimens described by Checchia-Rispoli do not fall into either of these two groups. They seem to be intermediate. On text-fig. 20-1, height relative to length, his specimens occur between the two paths for Form A and B. It would be difficult to differentiate his specimens from those of either of these two forms. Because of this it seems best not to consider these forms as separate species or varieties.

It is evident that Form B occurs in a higher horizon than Form A. In one place the two forms were collected from the same section. At Burud (Macfadyen 1933, p. 84, strata section 37) Form A occurs at ϕ259, low in the Karkar series, and Form B at ϕ244, near the top of the series. As all the other localities where Form B occurs are





TEXT-FIG. *20*

Migliorinia migiurtina Checchia-Rispoli. 1. Length relative to height in Form A and B, and in Checchia-Rispoli's specimens. 2. Number of pore-pairs relative to length in Form A and B.

those of Barrington Brown, it is not possible to know their relative position in the series. However, it is possible to locate four horizons, p. 24, p. 20, ϕ 259, ϕ270, where Form A occurs and all of these horizons are low in the series.

Abnormality.—Among the specimens is a tetramerous variant. This specimen C2918 of Form B, has only four ambulacra, three interambulacra, two half-interambulacra, four genitals, and probably only three oculars. The test is very distorted (text-fig. 19b,c) with an oblique, instead of transverse anterior margin and an eccentric posterior extremity. The periproct is abnormally large with a right anterior extension. Petal I is absent and petal II extends posteriorly from the eccentric apical system. Unfortunately, it is impossible to see the plate sutures but it is probable that ocular I is missing. Orally, the peristome is oblique with only four ambulacra at its margin.

As there are only four ambulacra at the peristome, it is apparent that this abnormality dates from the embryonic stage of this echinoid, before any skeletal parts had formed. Ambulacrum I and its adjacent half-interambulacrum 1b joined with 5a to produce a dual interambulacrum. This disturbance also altered the rate of production of plates as there are only 10–11 pore-pairs in petal II, whereas, a normal specimen of this length, 15.8 mm., has approximately 15.

Comparison.—This species is most similar to *Migliorinia moelehensis* (Fourtau, 1909, p. 166) from the Middle Eocene of Egypt. Both species have tests of similar shape and size. In both of the species the periproct is partially visible from above, and the petals flush with the test. *M. migiurtina* is distinguished from this Egyptian species by its wider petals and less depressed anterior surface. The peristome is more anterior in *M. migiurtina.*

Distribution.—British and Italian Somaliland. Form B in the Upper Karkar series, and Form A in the Lower Karkar series.

Localities.—Form B—B.6, B.9, B.10, B.56, ϕ244—120 specimens. Form A—ϕ186, ϕ189, ϕ230, ϕ259, ϕ264, ϕ265, ϕ270, p. 20, p. 24—154 specimens.

There are a few poorly preserved specimens from ϕ248, ϕ269 which because of their bad preservation cannot be referred with any certainty to a Form.

Sedgwich Mus. Cat. Nos.—Form B—C2818–C21919, Form A—C13372, Form uncertain—C3173.

Genus EUPATAGUS L. Agassiz

Eupatagus L. Agassiz in L. Agassiz and Desor 1847, Ann. Sci. Nat. ser. 3, p. 19.

Type species.—*Eupatagus valenciennesii* Agassiz, by subsequent designation of Pomel 1883, p. 28.

Diagnosis.—Test of moderate size, low, long, with truncated posterior margin, slight keel. Apical system small, anteriorly eccentric, ethmolytic with four genital pores. Ambulacrum III non-petaloid, in slight groove. Petals closed, with wide interporiferous zones, conjugate pore-pairs. Petals II and IV very divergent. Both peripetalous and subanal fasciole present. Large tubercles confined within area circumscribed by peripetalous fasciole.

Remarks.—Lambert (1920b p. 48) substituted the name *Brissoides* for *Eupatagus* claiming that Klein's *Brissoides cranium* was the type. As Mortensen (1951, p. 248) has pointed out, Klein's type was so poorly preserved as to prohibit generic identification. Furthermore, the substitution of an almost unknown name for an old and well known name, whether systematically correct or not, is a very questionable procedure. Apparently no official action has been taken on this question as it was not discussed at the International Congress of Zoology in Paris in 1948.

EUPATAGUS CAIRENSIS P. de Loriol

Pl. 107, fig. 9

Euspatangus formosus de Loriol. 1880. Mém. Soc. Physique Genève, tome 27, pl. 11, fig. 4; non de Loriol, pl. 11, fig. 2–3.

Euspatangus cairensis de Loriol 1897. Mém. Soc. Physique Genève, tome, 32, p. 4–6, pl. 1, fig. 1. Fourtau 1898. Mém. Inst. égypt (Égypte). tome 3, p. 686. Fourtau 1899. Bull. Inst, égypt, 3 ser., tome 10 p. 56–58. Fourtau 1909. Mem. Inst. égypt (Égypte), tome 6, p. 162. Fourtau 1913. Cat. Invertébrés Fossiles L'Égypt, Terrains Tertiaries, Échinides Éocènes, p. 69.

Eupatagus Figarii Stefanini 1919. Boll. Soc. geologica Italiana, v. 38, p. 44–46, pl. 2, fig. 2.

Diagnosis.—Test large with very slight anterior groove. Ambulacrum III almost

flush with test near apical system, but slightly depressed crossing ambitus. Petals almost flush, only poriferous zones depressed; interporiferous zones usually wide. Petals II and IV very divertent, slightly shorter than petals V and I. Periproct occurs high on vertical posterior truncation, not visible from above. Both peripetalous and broad, shield-shaped subanal fasciole present. Large tubercles occur within area circumscribed by peripetalous fasciole.

Material.—Ten well preserved specimens.

Remarks.—This species was previously described from the Middle Eocene (Lutetian II) of Egypt. De Loriol first considered the type specimen as *Eupatagus formosus* de Loriol, but later refigured it as a new species *E. cairensis*. Fourtau re-examined the species and considered it as a "mutation" of *E. formosus*, which occurs lower in Lutetian I. *E. cairensis* is easily distinguished from *E. formosus* as its test is more depressed, being flattened aborally, the interporiferous zones are much narrower, with their greatest width near the apical system, and the petals are shorter.

Some of the specimens in this collection are indistinguishable from Stefanini's *Eupatagus figarii* from the Eocene of Egypt. Stenfanini failed to compare his specimens of *E. cairensis*. With little doubt, *E. figarii* should be considered as synonymous with *E. cairensis*.

In one specimen, C2633, interambulacral columns 2b and 3a are isolated from ocular III indicating that production of new plates had ceased for these areas.

Comparison.—This species is similar to *Eupatagus dainellii* also from the Karkar series. Both species have similar petal arrangement. In *E. dainellii* the posterior truncation is oblique, tilting towards the aboral surface, resulting in the periproct being visible from above. The greatest width of the test is posterior to the center in *E. dainellii*, but anterior in *E. cairensis*.

Distribution.—Karkar series (Middle Eocene) of British Somaliland. Probably from high in series, as it occurs with *Migliorinia migiurtina*, Form B, found near the top of section at Burud. Species also occurs in Middle Eocene of Egypt.

Localities.—B.13, B.27 (Sedgwick Mus. Cat. Nos. C2625, C2627–35).

EUPATAGUS DAINELLII (Checchia-Rispoli)
Pl. 107, fig. 10–13

Brissoides Dainellii Checchia-Rispoli 1944. Mem. R. Accad. Italia, v. 14, p. 105–107, pl. 1, fig. 3–6.

Diagnosis.—Test of moderate size, with greatest width posterior to center. Anterior surface blunted with only very slight anterior groove. Posterior truncation oblique, tilting towards aboral surface, with periproct visible from above; sternum very inflated. Petals II and IV very divergent, with poriferous zones IIb and IVa only slightly developed near apical system. Petals V and I longer than II and IV, pendent, with very wide interporiferous zones. Both peripetalous and small, cordiform-shaped subanal fasciole present. Large tubercles occur within area circumscribed by peripetalous fasciole.

Material.—Eighty-six specimens, very weathered, some fragmental.

Comparison.—Of all the Eocene species of *Eupatagus*, this species resembles most *E. daradensis* (Lambert 1936, p. 357) from the Lower Eocene of Senegal. Both are small forms with oblique posterior truncations, with their periprocts visible from above. However, *E. dainellii* is easily distinguished by its lack of a pronounced anterior groove, and by having its greatest width posterior to the center instead of anterior as in *E. daradensis*. Furthermore, it lacks an anterior extension of its right anterior side which is so prominent in the species from Senegal.

E. dainellii is easily distinguished from the Egyptian species. The shape of its test, with its greatest width posterior to its center, and its periproct being visible from above easily separates it from *E. formosus* and *E. cotteaui* de Loriol (1880, p. 136,139). It differs from *E. minimus* Fourtau (1909, p. 164) also from Egypt by having petals V and I more flexuous, and petals II and IV less divergent.

E. dainellii is very similar to *Migliorinia migiurtina* Form A, also from the Karkar series. Both species have very similar tests as they are both depressed with the greatest width posterior to the center. In both, the posterior truncation is oblique with the periproct visible from above. Also they both have a large, anterior peristome, and flush petals. *E. dainellii* is distinguished by its

wider interporiferous zones, and by the presence of large primary tubercles within the area circumscribed by the peripetalous fasciole.

Migliorinia migiurtina Form B is easily distinguished by its higher test.

Distribution.—Karkar series (Middle Eocene) of British and Italian Somaliland.

Localities.—ϕ182, ϕ186, ϕ189, ϕ258, ϕ264, ϕ265, ϕ269, ϕ270, p. 24, p. 30, B.12 σ202. (Sedgwick Mus. Cat. Nos. C2626, C3171–72, C3174–78).

Eupatagus fecundus (Checchia-Rispoli) Pl. 107, fig. 14–15

Brissoides fecundus Checchia-Rispoli 1944. Mem. R. Acad. Italia, v. 14, p. 109–111, pl. 3, fig. 1–4.

Diagnosis.—Species characterized by low, very elongate test. Apical system ethmolytic with four genital pores, very eccentric anteriorly. Ambulacrum III flush with test aborally, only very slightly depressed where it crosses ambitus. Petals flush with test, with narrow interporiferous zones. Petals II and IV very divergent, much shorter than petals V and I. Both peripetalous and very broad subanal fasciole present. Large tubercles occur within area circumbscribed by peripetalous fasciole.

Material.—One fairly well preserved specimen, C2636.

Comparison.—This species is not in the least similar to any of the Indian or Egyptian species of *Eupatagus*. None of these species have such an elongate, depressed test.

Distribution.—Karkar series (Middle Eocene) of British and Italian Somaliland.

Locality.—B.13 (Sedgwick Mus. Cat. No. C2636).

Eupatagus sp. cf. E. cordiformis Duncan & Sladen

Euspatangus cordiformis Duncan & Sladen 1884, Palaeontologia Indica, ser. 14, v. 3, p. 238–240, pl. 38, fig. 14.

Material.—Twenty-one broken, silicified and iron-stained specimens. None of specimens well enough preserved to show many features of species.

Description.—Test large, broad, with distinct anterior groove, inflated interambulacra. Petals depressed into shallow grooves; interporiferous zones extremely narrow. Petals II and IV very divergent, slightly flexuous, shorter than petals V and I. Posterior extremity truncated slightly obliquely with periproct visible from above. Peristome preserved in none of specimens. Both peripetalous and subanal fasciole present. Large tubercles occur in area circumscribed by peripetalous fasciole.

Remarks.—These specimens resemble *E. cordiformis* from the Middle Eocene of India. Their shape is similar to the Indian species as they both have an angular, heart-shaped test with a pronounced but gently curved anterior groove. Their petal arrangement is similar with petals II and IV slightly flexuous. However, the interporiferous zones in the Somaliland specimens appear to be narrower. It is impossible to decide whether or not these specimens belong to the Indian species, as not only are they poorly preserved, but the Indian species is based on one poorly-preserved specimen.

Comparison.—These specimens are easily distinguished from the other species of *Eupatagus* found in the Karkar series. They are distinguished from *E. dainellii* by their narrow petals with very narrow interporiferous zones. The tests have their greatest width anterior to the center; it is posterior in *E. dainellii*. Their petals are also narrower than those of *E. cairensis*. They are further distinguished from *E. cairensis* by their oblique posterior truncation. These specimens bear no resemblance to *E. fecundus* which has a much more elongated test with longer petals V and I.

Distribution.—Auradu series (exact position in series not known) of British Somaliland.

Localities.—ϕ163, ϕ159 (Sedgwick Mus. Cat. Nos. C3093–96).

Genus Brissopsis L. Agassiz

Brissopsis L. Agassiz 1840, Cat. syst. Ect Echino. foss. Mus. Neo., p. 3, 16.

Type species.—*Brissopsis lyrifera* (Forbes), by subsequent designation of Agassiz and Desor, 1847, p. 14.

BRISSOPSIS sp. cf. B. RAULINI Cotteau
Pl. 107, fig. 16,17

Brissopsis raulini Cotteau 1886. Paléont. Française, Terrains Tertiaire, Échinides Éocenès, tome 1, p. 187–190, pl. 54.

Material.—One poorly-preserved specimen with petaloid area badly weathered and pitted.

Description.—Test large, flattened, with distinct anterior groove, and vertical posterior truncation. Greatest width anterior to center, greatest height posterior at inflated sternum. Apical system very eccentric anteriorly, ethmolytic with four genital pores. Ambulacrum III nonpetaloid, depressed in shallow, gently sloped depression forming distinct but slight groove where it crosses ambitus. Petals depressed, narrow, with very narrow interporiferous zones. Petals II and IV very divergent with poriferous zones IIb and IVa slightly developed near apical system. Petals V and I longer than II and IV, converging towards each other near apical system, but diverging from each other near their extremities. Within petaloid region all interambulacra, except interambulacrum 5, slightly inflated. Interambulacrum 5 very depressed almost to level of petals. Periproct occurs on vertical posterior truncation at ambitus, elongated longitudinally. Character of peristome not clear but apparently large. Portions of subanal and peripetalous fasciole visible.

Remarks.—This specimen resembles *Brissopsis raulini* from the Middle Eocene of France. It is similar in petal arrangement, having petals II and IV very divergent, and petals V and I converging near apical area, and diverging near their extremities. Its shape is also very similar with its greatest width anterior to the center and its posterior truncation almost vertical. In this specimen the apical system is more anterior and its petals are narrower with petals V and I longer than in *B. raulini*. Probably this species represents a new species, but its poor preservation prohibits such description.

Distribution.—Karkar series (Middle Eocene) of British Somaliland.

Locality.—ϕ202 (Sedgwick Mus. Cat. No. C3196).

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EXPLANATION OF PLATE 107

All figures ×1

FIG. *1–5—Migliorinia migiurtina* Checchia-Rispoli, form B. *1*, aboral view of specimen C2869, showing flush petals with narrow interporiferous zones; *2*, oral view of same specimen. *3*, view of right side of another specimen, C2863, showing high test typical of Form B; form A. *4*, aboral view of specimen C13372; 5, View of right side of same specimen showing low test relative to Form B.

6–8—Arcaechinus auraduensis n. sp. *6*, aboral view of holotype, C2996, showing coffin-shaped test; *7*, posterior view of same specimen showing wide reniform-shaped subanal fasciole (marked with chalk); *8*, aboral view of paratype C2986, showing apical system with three genital pores, and peripetalous fasciole (marked with chalk).

9—Eupatagus cairensis P. de Loriol. Aboral view of specimen C2625.

10–13—Eupatagus dainellii (Checchia-Rispoli), *10*, Aboral view of specimen C3176 showing wide petals with poriferous zones IIb and IVa slightly developed near apical system. Area around periproct fractured; *11*, posterior view of same specimen showing small shield-shaped subanal fasciole (marked with chalk); *12*, oral view of same specimen; *13*, view of right side of same specimen.

14–15—Eupatagus fecundus (Checchia-Rispoli). *14*, aboral view of specimen C2636 showing elongate test, very anteriorly eccentric apical system, and long petals V and I. *15*, view of right side of same specimen showing depressed test.

16–17—Brissopsis sp. cf. *B. raulini* Cotteau, *16*, view of right side of specimen C3196; *17*, aboral view of same specimen.

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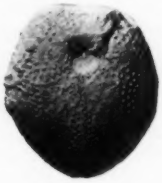

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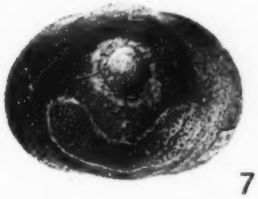

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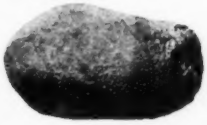

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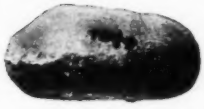

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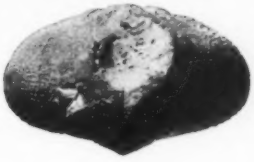

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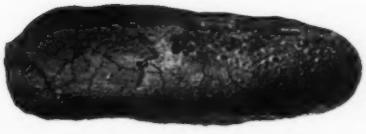

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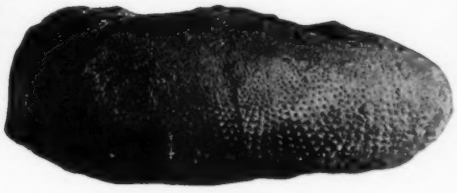

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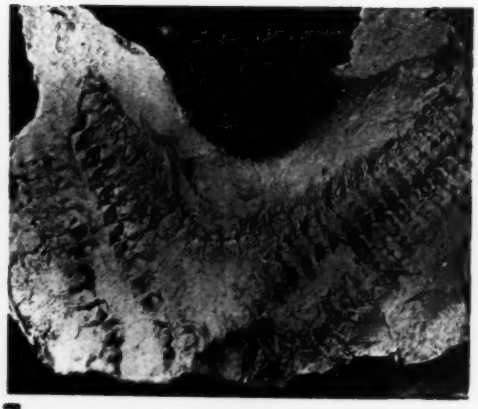

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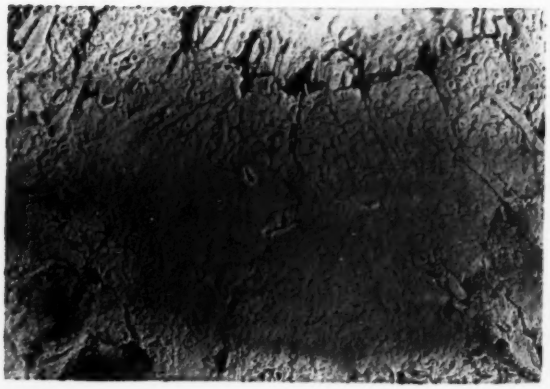

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JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 903–907, PL. 108, 1 TEXT-FIG., SEPTEMBER 1957

ORDOVICIAN STARFISH FROM THE MARTINSBURG SHALE, SWATARA GAP, PENNSYLVANIA

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ABSTRACT—*Taeniaster spinosus* (Billings) and *Promopalaeaster pricei*, n. sp., are described from the Martinsburg shale of Edenian age at Swatara Gap in southeastern Pennsylvania. The nature of the starfish remains and related fossils suggest a depositional environment of quiet water with an occasional influx of silty material.

INTRODUCTION

A QUARRY in Swatara Gap, Lebanon County, Pennsylvania (text-fig. *1*), has exposed about 100 feet of the Upper Ordovician Martinsburg shale, in which over fifty specimens and fragments of starfish have been collected in about 300 man-hours of random sampling. This is an excellent collecting ratio.

Photography is by Robert Ellison.

STRATIGRAPHY

The exposed section is near the upper part of the Martinsburg shale. Talus from the Silurian Tuscarora quartzite makes the determination of the precise stratigraphic level of the section impossible, but the exposure is probably within fifty feet of the top, and certainly not more than 100 feet below it.

Overling the Martinsburg shale in this locality is the Bald Eagle conglomerate. While Stose (1930) considered this formation to be Silurian, later work has shown it to be Upper Ordovician Maysvillian (Twenhofel, et al., 1954).

Extensive collecting at this locality by Stose (1930) and nearby by Moseley (1950) has established an Edenian age for that part of the Martinsburg shale exposed at Swatara Gap. Neither of these authors, however, reported the presence of starfish.

PETROGRAPHY

The Martinsburg in the quarry is a monotonous sequence of fossiliferous, dark gray and brown shale which weathers dark brown to gray. It is thin bedded, and any thick slabs can be easily split along incipient planes into thin chips. Smooth, even planes are uncommon, however.

An occasional feldspar grain about ½ mm in diameter can be seen on a fresh surface, and locally small, rounded manganese nodules occur. Manganese dendrites are also common.

In thin section, the Martinsburg shale appears to be composed of about 50 per cent subangular, near-clay-sized detrital quartz fragments, and 50 per cent clay minerals. In the places where the detrital material is more concentrated a definite banding, or lamination, is evident.

Throughout the section are gray and brown, finely-bedded siltstones which weather dark gray and brown. The beds are at most two inches in thickness.

Sedimentary structures, locally interpreted as storm rollers, are present, but more detailed study is necessary to determine the true nature of these features.

NATURE OF THE FOSSILS

The rich fauna is almost entirely shown by external molds into which ground water

EXPLANATION OF PLATE 108

FIG. *1,2*—*Taeniaster spinosus* (Billings) *1*, oral view, showing normal crawling position; Martinsburg shale, Ordovician, Swatara Gap, Lebanon County, Pennsylvania; ×1.6. *2*, oral view of the mouth-frame area; ×15.

3,4—*Promopalaeaster pricei*, n. sp. *3*, oral view, Holotype, USNM 128252; ×1.6. *4*, oral view showing interbrachial area and spinose, pustulose interbrahcial marginals; Holotype, USNM 128252; 15.

has precipitated iron oxide. The impressions show that the fossils were preserved in their entirety, with very little *post-mortem* damage. Delicate crinoid arms with pinnules, crinoid stems, bryozoans, graptolites, and many other easily-disarticulated types are well preserved, generally intact. Pelecypod and brachiopod shells are commonly found articulated; the orthoconic nautiloids retain their circular cross section, although many are flattened and cracked down the longitudinal axis; and trilobites are found both intact and disarticulated. The starfish are mostly intact; no isolated parts are found. Those found in the expanded crawling position were not disarticulated.

Although a few fossils are found oriented with their long axes at an angle to the bedding, most are oriented with their axes parallel to the bedding.

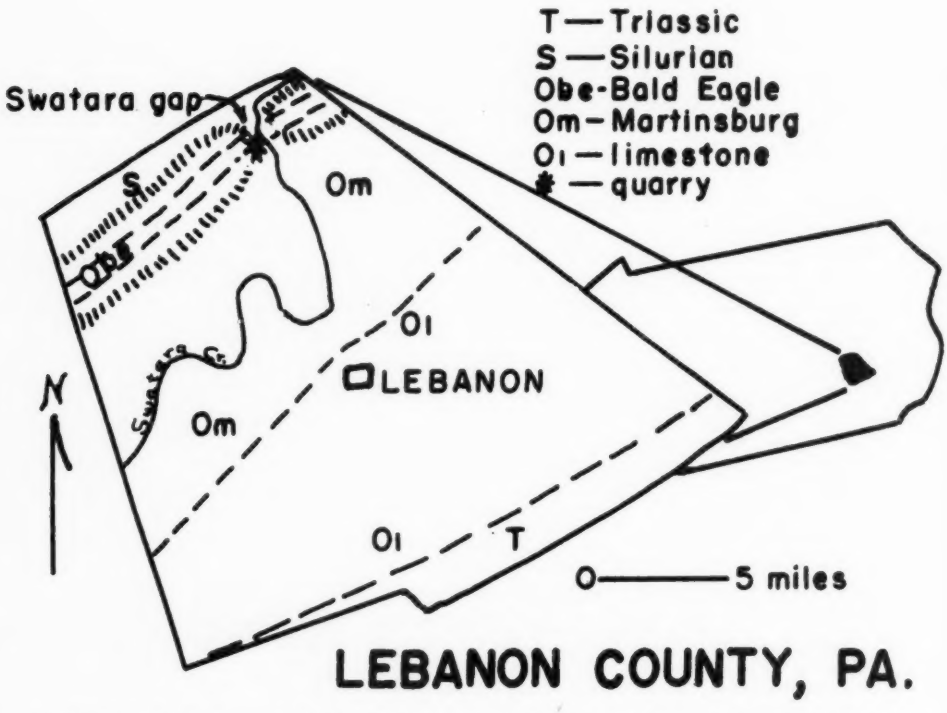
PALEOECOLOGY

The fossils are present throughout the entire exposed section with no apparent preferred grouping, either biological or statistical, except for their absence in the thin siltstone beds.

A quiet-water environment is suggested by the excellent preservation of delicate fossils, especially the crinoids and starfish. The siltstone beds indicate an occasional influx of coarser material.

Inasmuch as Ophiuroidea burrow into the bottom mud for eating purposes, they are already buried and not exposed to the bottom currents which may exist when they die, and so would be preserved from disarticulation. Those Ophiuroidea which were found at Swatara Gap in the burrowing position had all of their arms extended in one direction, often with the distal ends gone. A few of those which were found in this position were oriented with the long axis of the ophiuroid perpendicular to the bedding. In such specimens, the arm tips, protruding out of the mud, were removed by the currents or by slow decomposition.

Not all starfish died in the burrowing



TEXT-FIG. *1*—Index map showing location of quarry from which starfish were obtained.

position, however, as many of those at Swatara Gap were found expanded in the normal crawling position.

If smothering by rapid sedimentation had been the cause of the death of the starfish (which is unlikely because they are mobile), one would expect to find disarticulated ossicles scattered throughout the sediments because of the energy present. This is nowhere evident.

Most of the Ophiuroidea are preserved as molds, generally of the oral surface. The counterpart is generally a cast of the oral surface. Rarely is the aboral surface molded. This suggests that the starfish may have impressed their features on the soft bottom mud, were *slowly* disarticulated, eaten, or decomposed, and more mud was gently deposited in the mold. Another possibility of this mode of preservation is that the entire starfish was covered, and after the ossicles decomposed, the mold of the aboral surface "caved in" and was destroyed. The material which "caved in" made a cast of the oral surface. The latter mode of preservation seems more reasonable, as some of the molds show many of the delicate internal parts of the arms which could only be molded by a completely covered corpse.

Although the water was apparently deep enough to be free of strong bottom currents and wave action most of the time, the rich and varied fauna indicates that the water was shallow enough to permit sunlight to penetrate to the bottom. The large population could only have been supported by a large amount of algae as the start of the food chain.

SYSTEMATIC PALEONTOLOGY

Four genera have been recognized from Swatara Gap; one of the species is new. Two genera are discussed in this article; the other two, *Hallaster* and *Mesopalaester*, have been reported from this locality (Price, pers. comm., 1955) but have not been formally described. The writer did not find any representatives of these two genera in the quarry.

Subclass ASTEROINEA
Order PUSTULOSA Spencer, 1951
Family PROMOPALAEASTERIDAE Schuchert, 1914

Subfamily PROMOPALAEASTERINAE Schuchert, 1914

Genus PROMOPALAEASTER Schuchert, 1914

Spencer, (1934, p. 91) describes this genus as follows:

> Progressive Promopalaeasterinae with the interbrachial areas complex and composed of a single axillary interbrachials [odontophores], more than one pair of interbrachial marginals, and adambulacral plates. Podial openings in each ambulacral furrow mainly in two columns, but proximally there may be two additional ones in a length never more than one third the ray.

There is little doubt that the specimen described in this article is of this genus. The odontophore and any other plates which may be in the axillary region, except the adambulacrals, of which there are two pairs, are absent. This is typical in the echinoderm integumental structure. The specimen described has six interbrachial marginals, all spinose. There are only two rows of proximal podial openings.

PROMOPALAEASTER PRICEI, n. sp.
Pl. 108, fig. 3,4

R, minimum 32 mm.
r, minimum 10 mm.

Discussion.—Unfortunately the holotype, although preserved excellently, is incomplete. Only one half of the arms are preserved, suggesting that the radius is near 60 mm., or nearly 5 inches in diameter. This is an exceptionally large asteroid for Ordovician time. *Promopalaeaster pricei* most nearly resembles the known specimens of *P. magnificus* (Miller).

Promopalaeaster pricei and *P. magnificus* have four major differences, which seem to be significant enough to warrant the erection of a new species.

Promopalaeaster pricei has longitudinally striated spines, whereas Schuchert (1915, p. 124) and Spencer (1934) point out that *P. magnificus* has smooth spines.

The interbrachial area in *Promopalaeaster pricei* is large enough to accommodate a larger odontophore than those which are possessed by *P. magnificus* as figured by Schuchert (1915). This larger axillary area in *P. pricei*, however, could be the result of flattening during preservation

wherein the marginal interbrachials are squeezed outward.

Another difference between *Promopalaeaster pricei* and *P. magnificus* is that the former has six interbrachial marginal plates, whereas the latter, according to Spencer (1934, p. 79) has only five. It could be argued, possibly, that the sixth interbrachial marginal in reality is an inferomarginal which has been separated from its articulating adambulacral by *post-mortem* flattening and so appears in the axillary region.

The most significant difference between *Promopalaeaster pricei* and *P. magnificus* is the difference in stratigraphic position. *P. pricei* is Edenian, whereas *P. magnificus* is Richmondian. The starfish as a group have so little fossil representation and so few scholars have investigated them, in comparison with other fossil groups, that the stratigraphic ranges of individual species or groups is not fully known. The little work which has been done does not indicate that individual species have a wide stratigraphic range.

Location and age.—Martinsburg shale, Edenian age, Swatara Gap, Lebanon County, Pennsylvania.

Material studied.—One well preserved specimen was found, USNM no. 128252, (Pl. 108, fig. 3,4). Several identifiable but poorly-preserved fragments were also found.

Remarks.—The name is offered to honor Dr. John W. Price of the North Museum, Lancaster, Pennsylvania who has collected and saved many of the starfish from Swatara Gap.

Subclass OPHIUROIDEA
Order OPHIURIDA Spencer, 1950
Suborder OEGOPHIURINA Spencer 1950
Superfamily LYSOPHIURICAE Spencer 1950
Family PROTASTERIDAE Spencer, 1922
Genus TAENIASTER Billings, 1858

Spencer (1934, p. 484) describes *Taeniaster* as follows:

> Adambulacralia in proximal and medial arm-regions set vertically to the groove, except occasionally in some of the large, later species where they may be set at an angle. Oral edge of the adambulacralia sharp, standing up from the main mass of the ossicle; this edge, with nose, following the outline of a sickle. Both groove and vertical spines well developed. Ambulacral boots stout, cups for tube feet large.

TAENIASTER SPINOSUS (Billings) 1858
Pl. 108, fig. 1,2

R, minimum 35 mm.
r, minimum 5 mm.

Discussion.—This is an exceptionally large specimen of *Taeniaster spinosus;* the type specimen is much smaller. Spencer (1934, p. 441) however, points out that specimens, even larger than that shown in Plate 1, fig. 1,2 are known.

This specimen has many well preserved vertical spines; the groove spines are not as well shown. There are raised areas near the oral surfaces of the ambulacrals which could be interpreted as the remains of groove spines that were once attached at these points. The spines are apparently hollow and striated.

The specimen illustrated in pl. 108, fig. 1 has a well defined disc which is apparently composed of fine plates enclosed by a leathery integument. The gross aspect is granular on the oral surface. No marginal disc plates are present. The madreporite is on the aboral surface in *Taeniaster* and not present in this view.

The mouth-frame is exceptionally well preserved. Three mouth spines on each torus project into the buccal area. The articulation of the mouth-angle plates and the first ambulacral plates is well exposed. The water vascular ring, which is ordinarily very clear on such exposures, is not well preserved. The presence of the ring is shown by a canal leading to the first and second tube feet on the ambulacral plate (pl. 108, fig. 2).

Location and age.—Martinsburg shale, Edenian age, Swatara Gap, Lebanon County, Pennsylvania.

Material studied.—Several extremely well preserved specimens and over 50 identifiable fragments were available for study.

Taeniaster spinosus was found in considerable abundance at Swatara Gap. As many as seven starfish were found on a single hand specimen of Martinsburg shale. Starfish are found in both the burrowing position, with the five arms oriented in the same direction, and the expanded travelling position.

Remarks.—The most common species in the genus *Taeniaster* is *spinosus.* A number of other species have been proposed since its

erection in 1858, but Spencer (1934) has pointed out that many are synonymous with *spinosus* or can be more properly placed in other genera. One of these is *T. maximus* Willard, 1937.

Willard proposed the species for a specimen found in a similar stratigraphic position as the one reported here, but from a locality about 20 miles away. His holotype has been lost, however, and is not available for study.

Taeniaster maximus is much smaller than the *T. spinosus* (pl. 108, fig. 1), but Spencer mentions *spinosus* whose size-range encompasses that of *maximus*. Although *T. maximus* is larger than the holotype, *T. spinosus*, the specimen of *spinosus* described in this article is unusually large. Clearly *spinosus* has a wide size-range which includes *maximus*.

Willard's (1937) illustration of *Taeniaster maximus* (Fig. 1, p. 622) shows his specimen in the burrowing position and the disc is not evident. *T. maximus* does not have any spines but Willard mentions the possibility of their being present. Spines are one of the most striking features of *T. spinosus*.

Willard considers the shape of the ambulacrals as a third difference between *Taeniaster maximus* and *T. spinosus*. He says, "*Taeniaster maximus* has a distinct comma-shaped adambulacrals, not slender and slightly curved like the rods of *T. spinosus*."

Spencer's work (1934, p. 489–490), of which Willard apparently was not aware, says:

> The side shields adambulacrals are thin, and in many respects similar to those carried by *Lapworthura* and *Hallaster*. They show sharp, crescent-shaped oral edges. On the outer edge of the crescent is a well-pronounced thickening formed by the vertical ridge. Interior to the sharp edge is a well-defined smooth area. Immediately below the area the *ossicle thickens somewhat abruptly, especially anteriorly*, where the thickening takes the form of a well-pronounced nose which fits into a groove on the ambulacral. In certain views, the presence of this pronounced nose makes the side shield adambulacral look sickle shaped, showing as a thin, sharply-defined edge. [Italics, H.R.C.]

Taenister maximus Willard is here considered a synonym of *T. spinosus* because of the similarity of morphology and stratigraphic position.

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MANUSCRIPT RECEIVED NOVEMBER 16, 1956.

JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 908–912, 3 TEXT-FIG., SEPTEMBER 1957

BELEMNITELLA PRAECURSOR FROM THE NIOBRARA FORMATION OF KANSAS

HALSEY W. MILLER, JR.
State Geological Survey of Kansas, Lawrence, Kansas

ABSTRACT—Of the twelve specimens of *Belemnitella praecursor* Stolley examined from the Niobrara formation of Kansas, two are described and figured. These belemnites are from the *Uintacrinus* beds or from strata below the *Uintacrinus* beds. They differ slightly from *Belemnitella praecursor media* Jeletzky described by Jeletzky as coming from the Niobrara formation of Kansas.

INTRODUCTION

JELETZKY (1955b) described a specimen of *Belemnitella praecursor* Stolley *media* Jeletzky, supposedly from the Smoky Hill chalk member of the Niobrara formation of Kansas. The specimen was in the geological museum of the University of Kansas and was labeled "*Belemnites*, U. K., Colorado." No other information as to locality, formation, or collector was available. The alveolus of the guard was filled with yellow chalk, which closely resembled the chalk of the Smoky Hill member. Jeletzky assumed that the word "Colorado" on the label meant "Colorado group" and that the specimen was one of the belemnites mentioned by Williston (1897, p. 241–243) from the Smoky Hill member in Logan and Gove Counties, Kansas.

Jeletzky was unable to locate any other belemnite specimens from the Niobrara formation during a three year search. No mention was made as to whether any field work had been done by him.

According to Jeletzky (1955b), the presence of beds in the Niobrara formation of Kansas bearing *Belemnitella praecursor media* permits the correlation of the top of the Niobrara formation with the lower part of the Campanian stage of Europe, rather than with the lower part of the Santonian stage as correlated by Cobban and Reeside (1952) (see text-fig. *3*).

In August 1956, the writer visited the Fort Hays Kansas State College Museum and examined twelve specimens of *Belmnitella* collected by George F. Sternberg and Merle Walker from the Niobrara formation in Kansas. These specimens were not available at the time Jeletzky (1955b) wrote his paper.

ACKNOWLEDGMENTS

The writer is indebted to Mr. George F. Sternberg of the Fort Hays Kansas State College for lending him two of the specimens of *Belemnitella* and granting him permission to publish descriptions and photographs of them.

DESCRIPTION OF SPECIMENS

The two large guards examined by the writer (text-fig. *1*) are each 89 mm. long; approximately 40 mm. of each guard is missing; the alveolar portion of the guard is broken off both specimens. The guards are slightly lanceolate when seen either from the dorsal or ventral position (text-fig. *1*B), and cylindrical when viewed from the lateral position (text-fig. *1*A). Both ends of each guard are tapered slightly, and the diameter of the guard decreases toward both ends. The ventral surface of the guard is slightly flattened at the base of the alveolus.

The dorsolateral depressions become farther apart posterior to the alveolus and are not distinguishable midway between the alveolus and the posterior end. The dorsolateral depressions grade into double dorsolateral grooves toward the apical end of each specimen. The dorsolateral grooves are nearly parallel and about 2.0 mm. apart. There is no measurable increase in width of the dorsolateral grooves toward the apical end. There is a faint raised line inside and parallel to the dorsolateral grooves near the apical end.

The dorsal side of the guard (text-fig. *1*C D) has papillate markings on the apical half of its surface. The papillate markings are larger toward the apex and extend around on the flanks, where they

TEXT-FIG. *1—Belemnitella praecursor* from Logan and Gove Counties, Kansas. A, specimen 7936-2, lateral view. B, specimen 7936-1, ventral view. C, specimen 7936-1, dorsal view. D, specimen 7936-2, dorsal view.

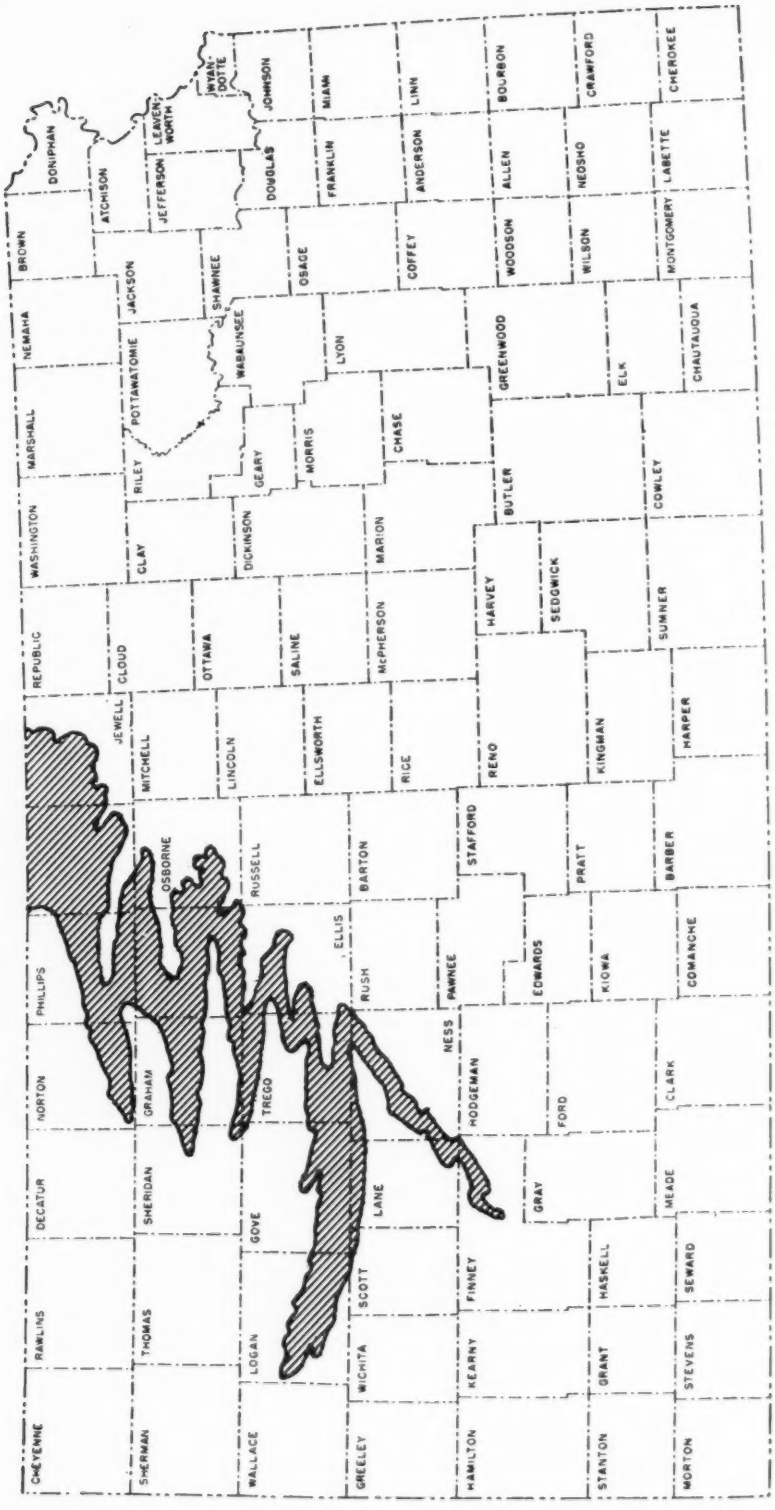
are smaller, and similar papillate markings seem to be present on the ventral surface of the guard near the apex. The papillae form weak oblique striations posterior to the alveolus on the ventral side. No longitudinal striations are evident on this specimen (7936–1). Faint longitudinal striations are present near the apex of specimen 7936–2, and the rest of this specimen is smooth. The other ten specimens examined were smooth-surfaced, some had been corroded, and presumably all had secondarily lost their ornamentation. All ten were less well preserved than the two specimens used for descriptive purposes.

No measurements of the alveolar region could be made on the specimens examined by the author, and the ventral surfaces of the two specimens show cracks below the alveolus that superficially resemble ventral fissures. These cracks seemingly developed when the alveolar portion of the guard was broken off.

The apical end of each of the two specimens was broken off, and no definite evidence of a mucro can be seen.

IDENTIFICATION OF SPECIMENS

According to Jeletzky (1955a), *Belemnitella praecursor* is characterized by weak sculpture or no sculpture on the guard. Weak striae and vascular imprints may be present. The guard is slender, 100 to 130 mm. long, tapering toward the apex, and subcylindrical to sublanceolate from the ventral aspect. The apical point is acute and may or may not be mucronate. The ventral fissure is short, 10 to 20 mm. long, and the alveolar cavity is shallow, being one-third to two-fifths the length of the guard. The conotheca has coarse ornamentation near the apex of the alveolus. Earlier Cretaceous species of *Belemnitella* have coarse conothecal ornamentation near the alveolar rim. The evolutionary trends in the development of *Belemnitella* (according to Jeletzky, 1955a) are expressed as: (1) a relative increase of alveolar depth, up to half



TEXT-FIG. 2—Generalized outcrop area of Niobrara formation in Kansas.

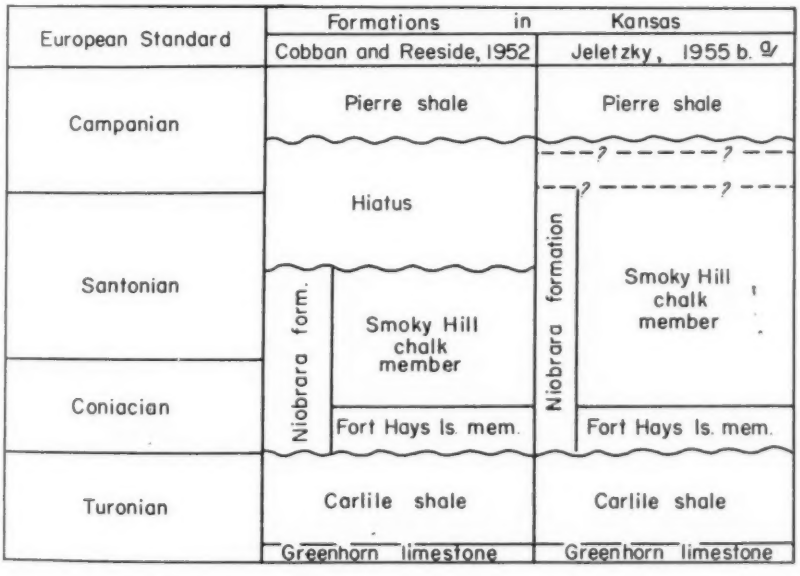
the length of the guard (this trend ceased in the late Campanian); (2) completely calcified guards by early Campanian time; (3) a gradual intensification of sculpture; and (4) development fo a mucronate apex.

The absence of the alveolar end of the guard in the specimens hampered identification. The remaining features of the guard fit within Jeletzky's definition of *Belemnitella praecursor*. The specimens differ from Jeletzky's specimen of *B. praecursor media*, in: (1) the lack of an increase in width of the double dorso-lateral grooves toward the apex; (2) the presence of faint longitudinal striae near the apex; and (3) the presence of the strongest papillae on the apical third of the dorsal side of the guard. Assignment of these two specimens to stratigraphically "high" or "low" forms of *B. praecursor* is complicated by the markings of specimen 7936–2 resembling those of a stratigraphically "low" form and the markings of specimen 7936–1 resembling those of a stratigraphically "high" or "intermediate" form. It is possible that the specimens came from different stratigraphic horizons, and "low" to "intermediate" or "high" *Belemnitella praecursor* subspecies are present within the Niobrara formation. In order to clarify the specific classifications of the Niobrara belemnites, a suite of several specimens from the same locality or stratigraphic zone in the Smoky Hill member should be studied.

LOCALITY AND STRATIGRAPHIC POSITION OF *Belemnitella Praecursor* IN KANSAS

Twelve specimens in the Fort Hays Kansas State College Museum were found in Logan and Gove Counties, Kansas (text-fig. 2). Mr. Sternberg (personal communication) states: "Since we have twelve different specimens, I am not able to tell you just where these specimens were picked up in Gove and Logan Counties. There is no question about them coming from the Niobrara. I expect I have found twenty or twenty-five good specimens in my life from the Niobrara formation."

In Logan and Gove counties, the outcropping Smoky Hill member consists of gray calcareous shale capped by yellow chalk, which forms the spires, pinnacles, and buttes known locally as the Chalk Bluffs, Chalk Pyramids, and Monument



a/ Interpreted from Jeletzky's paper, no chart was given by him.

TEXT-FIG. 3—Correlation of Niobrara formation.

Rocks. The *Uintacrinus* beds occur in the Smoky Hill member (in the Chalk Bluffs area) near Elkader, Logan County (Williston, 1897, p. 241–243). Presumably the belemnite beds coincide with the *Uintacrinus* beds in the upper half of the Niobrara formation, although the belemnite beds could extend from below the middle of the Niobrara formation in Gove County to the top of the Niobrara formation in Logan County, inasmuch as Sternberg has found specimens in both counties.

It is entirely possible that the upper part of the Niobrara formation in Kansas is younger than the upper part of the Niobrara formation in Colorado, as suggested by Jeletzky (1955b). However, the presence in the Niobrara formation of Kansas of a belemnite species which is normally restricted to the upper part of the Santonian and lower part of the Campanian stages of Europe, and the probable presence of a variety of belemnite restricted to the lower part of the Campanian stage of Europe are not sufficient evidence to change the correlation of the upper part of the Niobrara formation.

If subsequent field work should establish the presence of the *Marsupites* or *Desmoscaphites bassleri* in the upper part of the Niobrara formation of Kansas, then Jeletzky's correlations will have been confirmed.

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ARCHAEOCYATHA FROM THE LOWER CAMBRIAN OF THE YUKON TERRITORY

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ABSTRACT—Archaeocyatha from the Lower Cambrian of Wolf Lake and Quiet Lake areas in the Yukon Territory are described and illustrated. The fossils occur in carbonate rocks and are well preserved. Much of the necessary structural detail of the fossils is clearly observed in thin-sections and on polished surfaces of the specimens.

The collection contains twenty-three species, twelve of which are new. The genera *Carinacyathus* and *Loculicyathus* are reported for the first time in North America.

The Yukon fauna is dominated by Coscinocyathidae and Pycnoidocyathidae, showing close relationship to faunas in the Cordilleran region of British Columbia. It also shows relationship to Siberian and Australian faunae. This fauna is very different from the archaeocyathid assemblages in Nevada and California, where the dominant forms are Ethmophyllidae and Ajacicyathidae.

Archaeocyatha have been instrumental in determining the age of rocks underlying a large area of the Yukon Territory.

THIS study is based on specimens collected in the Yukon by Dr. W. H. Poole of the Geological Survey of Canada, Dr. Aaro Aho and Mr. W. Padgham of the British Yukon Exploration Company and Dr. Hans Trettin of the University of British Columbia. The specimens occur mainly in dark carbonate rocks which are fine-grained, massive to oolitic in texture. On the whole the fossils are well preserved, with a few replaced by calcite and a few fragmental because of the slaty nature of some limestones.

During the field seasons of 1951 to 1954 inclusive, Dr. W. H. Poole mapped the Wolf Lake Area, Yukon Territory (Department of Mines and Technical Surveys, Sheet 105B; Preliminary Map 55–21). The fossil localities are indicated on this map. The specimens studied for this paper came from the following localities:

(a) Geological Survey of Canada collection numbers 24035, 24040, and 24041, at latitude 69° 03′, longitude 130° 21′; 3 miles South 30° East from Veronica Lake near milepost 702 Alaska Highway. The specimens were collected from Lord's (1944) Group C sediments.

(b) Geological Survey of Canada collection number 24036, at latitude 60° 12′ 30″, longitude 131° 11′ 30″; 1 mile northeast from northeast end of Crescent Lake. Fossils were collected from Lord's (1944) Group B sediments.

Dr. Lord regarded Group B as probably Palaeozoic in age, while the overlying (?) Group C sediments were placed in the Carboniferous (?), on the basis of fossil corals identified as *Lophoplhyllum* (?) and *Hapsiphyllum* (?). Since Archaeocyatha are undoubtedly of Lower Cambrian age, we can conclude that Group B is entirely Lower Cambrian, and at least the lower part of Group C is Lower Cambrian. The possibility exists, however, that some Archaeocyatha were mistakenly identified as corals.

Dr. Aho and Mr. Padgham made their collection on a ridge which separates the headwaters of White Creek and Ketza River in the Pelly Mountains in the Quiet Lake Area (Department of Mines and Technical Surveys, National Topographic Series, Map Sheet 105F), Whitehorse Mining District, Yukon Territory. This area is accessible from two lakes on which planes can land: (a) Bruce Lake, from which thirty miles of trail leads up Ketza River, and (b) Grayling Lake, from which it is fifteen miles hike up White Creek. The area can also be reached in two days by horse from the Canol Road, which runs in a north-south direction about thirty miles to the east.

The exact fossil locality (latitude 61° 31′; longitude 132° 15′) is approximately 1000

feet northwest from the northwest corner of Kay No. 31 claim and on the trail leading to the Conwest camp which is eight miles northerly from this area. The locality is marked on a map accompanying Aho's (1955) report: "Geological Report on the Kay Group of Claims and Upper White Creek, Ketza River Area, Yukon Territory," which was submitted to the British Columbia Department of Mines as assessment work.

Rocks of the Kay Group of claims and adjacent upper White Creek area, as reported by Aho, consist chiefly of marine sediments which have been folded, faulted, and weakly metamorphosed. Phyllite, limestone, dolomite, and quartzite are the main rock types. The Lower Cambrian limestones and phyllites are exposed along a North 70° West anticlinal fold. The following stratigraphic sequence of the area, in descending order, is reported by Aho:

Apparent Stratigraphic Section at Upper White Creek	Thickness
White brown, and gray massive pyritic quartzite, minor greenish gray chert, limestone and phyllite with ankerite (?), impure quartzite and gradations to limy schists and minor green phyllite	Several hundred feet
Black phyllite or slate (may contain local slaty limestone)	100 feet
Massive to thin bedded, buff-weathering dolomite with local chert nodules and thin ribbon chert beds	100 to 200 ft.
Thin bedded slaty limestone and oolitic limestone (locally absent)	50 feet
Brown phyllite (locally limy) grading downward to gray and black phyllite	500 feet
Blue-gray, massive, fossiliferous Lower Cambrian limestone	150 to 200 feet
Several beds of slaty or shaly limestone alternating with grayish brown phyllite and grading downward into gray phyllite at least several hundred feet thick with minor limy and sandy beds	

Aho states that the rocks crop out in this sequence at this locality, but does not preclude some degree of thickening by thrusting or isoclinal drag folding, especially in the incompetent phyllite members. The regional geology of the area is not known at the present time.

In the following description of species, fossils collected by Aho and Padgham are designated by letters AP and the specimen number. Fossils from the Geological Survey of Canada collection are marked with the letter Y preceded by a two digit number and followed by the specimen number, for example, 35-Y-1. The first number is taken from the last two digits of the Geological Survey of Canada collection number (24035) and 1 is the specimen number. The Holotypes, Paratypes, and some other exceptionally good specimens from the Survey collection are in addition assigned regular Survey numbers ranging from 13325 to 13352.

FAUNAL LIST

Phylum ARCHAEOCYATHA
Class ARCHAEOCYATHEA
Order AJACICYATHIDA

Family Ajacicyathidae
- *Ajacicyathus purcellensis* Okulitch
- *Ajacicyathus yukonensis*, n. sp.

Family Ethmophyllidae
- *Ethmociscinus sp.*

Family Coscinocyathidae
- *Coscinocyathus dentocanis* Okulitch
- *Coscinocyathus multiporus*, n. sp.
- *Coscinocyathus cassiariensis*, n. sp.
- *Coscinocyathus inequivallus*, n. sp.
- *Coscinocyathus serratus*, n. sp.
- *Coscinocyathus tubicornus*, n. sp.
- *Coscinocyathus* sp.
- *Carinacyathus perforatus*, n. sp.

Order METACYATHIDA

Family Archaeocyathidae
- *Archaeocyathus cf. atlanticus* Billings
- *Archaeocyathus* (?) sp.

Family Pycnoidocyathidae
- *Pycnoidocyathus amourensis* (Okulitch)
- *Pycnoidocyathus columbianus* (Okulitch)
- *Pychnoidocyathus cf. occidentalis* (Okulitch)
- *Pycnoidocyathus cf. dissepimentalis* (Okulitch)
- *Pycnoidocyathus solidus*, n. sp.
- *Loculicyathus ellipticus*, n. sp.

Family Metacoscinidae
- *Metacoscinus poolensis*, n. sp.

Metacoscinus sp.
Claruscyathus ketzaensis, n. sp.

DESCRIPTION OF SPECIES

Order AJACICYATHIDA Bedford & Bedford, 1939

Family AJACICYATHIDAE Bedford & Bedford, 1939

AJACICYATHUS PURCELLENSIS Okulitch
Pl. 109, fig. 1

Ajacicyathus purcellensis Okulutch, 1947

General shape and size.—This is a common species found in the Lower Cambrian formations of the northern Cordilleran region. The specimens from the Wolf Lake Area, Yukon are short fragments of a form originally gently tapered and conical with a naturally elliptical cross-section. The following are the average dimensions taken from four specimens:

Diameter	25	mm.
Diameter of central cavity	16	mm.
Width of intervallum	6	mm.
Number of parieties	73	
Intervallum coefficient	0.38	
Parietal coefficient	2.92	

Outer wall.—The outer wall is thin, simple, and perforated by numerous fine pores, about 3 or 4 per intersept.

Intervallum.—The medium wide intervallum is crossed by a moderate number of straight, radiating parieties. Parieties, spaced about 1 mm. apart, are thin, simple, and perforated by a number of small pores.

Inner wall.—The inner wall appears simple and perforated by pores, about 2 to 3 per intersept. In all specimens examined, the inner wall and parts of the intervallum are replaced by calcite. Thus much of the pore arrangements is obliterated.

Collection.—Geological Survey of Canada, collection no. 24035 Specimen nos. 35-Y-5, 6, 7. (G.S.C. No. 13325) Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—The specimens of *Ajacicyathus purcellensis* Okulitch, from the Yukon are almost identical in characteristics to those found in the Donald formation of the Dogtooth Mountains and in the Upper Wolverine complex of Aiken Lake Area. No addition or amendments can be made to the original description.

AJACICYATHUS YUKONENSIS, n. sp.
Pl. 109, fig. 2

General shape and size.—Description of this species is based on a single specimen from which a transverse thin-section was prepared, and appears on the same glass slide as *Coscinocyathus multiporus*, n. sp. It is a relatively small conical form which is slightly elliptical in transverse section.

Diameter	7– 9	mm.
Diameter of central cavity	3.2	mm.
Width of intervallum	2– 2½	mm.
Number of parieties	17	
Intervallum coefficient	0.71	
Parietal coefficient	2.21	

Outer wall.—The outer wall is thin, simple, and perforated by numerous small pores, up to six per intersept. The closely spaced fine pores give the wall, in cross-section, a minute "ripply" chain-like appearance. Stirrup pores are located along the intersection of the parieties with the outer wall.

Intervallum.—The intervallum is relatively wide and crossed by seventeen straight, radiating parieties of which two are short, incomplete, and interstitial. The parieties appear to be imperforated, but may have pores near the inner wall. Thickening of the parieties occurs where they join the outer wall and also slight thickening occurs at the inner wall.

Inner wall.—The inner wall is thickened and perforated by pores in a vertical series of about three per millimeter. Stirrup pores appear to be present.

Collection.—Geological Survey of Canada; collection no 24035. Holotype is specimen 35-Y-13. I., G.S.C. No. 13326. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments), Wolf Lake Area, Yukon.

Discussion.—The widely spaced, almost imperforated parieties and the pore arrangements of the walls resemble *Archaeocyathellus*, but the lack of distinct flutings or furrows of the outer wall opposite the parieties and the larger size undoubtedly place this specimen with *Ajacicyathus*. The wide intervallum region and low parietal coefficient of this species are unlike any known *Ajacicyathus* except possibly the larger *Ajacicyathus khemtschikensis* (Vologdin), but they differ in the form of the

loculi. The low parietal coefficient of *Ajacicyathus yukonensis*, n. sp., may not be of specific importance because recent investigations made by Zhuravleva (1955) on the growth stages of *Ajacicyathus khemtschikensis* (Vologdin) have revealed that at small diameters, this species has a very high parietal coefficient, but as the diameter increases, the parietal coefficient decreases accordingly. At a diameter of 2.0 mm. the parietal coefficient was found to be 5.5, at 4.5 mm., 4.0, and at 5.0 mm., diameter at maturity, the parietal coefficient was 3.0. From this she concludes that the coefficient becomes constant only when the organism has reached maturity; therefore, it is not a reliable criterion to use in identifying this species in the adolescent stages. This statement is worth noting because it may be applicable to other species but was not studied on *Ajacicyathus yukonensis*, n. sp. The pore patterns and the appearance of the intervallum of the later are sufficiently distinct from other species to justify the new species.

Family ETHMOPHYLLIDAE Okulitch, 1943
ETHMOCOSCINUS (?) sp.
Pl. 109, fig. 3

General shape and size.—A single, subcylindrical fossil fragment with an elliptical cross-section is noted in this collection. It is about 45 mm. long with the lower portion missing.

Diameter	19–22 mm.
Diameter of central cavity	4 mm.
Width of intervallum	8– 8½ mm.
Number of parieties	35
Spacing of tabulae	1– 6 mm.
Intervallum coefficient	2– 2¼ mm.
Parietal coefficient	1.7

Outer wall.—The outer wall of this specimen is relatively thick and perforated by large pores, about 1 or 2 per intersept.

Intervallum.—The very wide intervallum region is crossed by irregular parieties which are perforated by large pores and thickened near the inner wall. The intervallum is further occupied by porous tabulae spaced at irregular intervals.

Inner wall.—The *Ethmophyllum*-type inner wall is the most characteristic feature of this specimen. The inner wall is wide and perforated by very coarse oblique canals. In transverse section, these oblique canals appear as 3 or 4 rows of vesicular tubes lining the inner wall.

Collection.—Department of Geology, University of British Columbia; specimen no. AP 7.

Collected by Aho and Padgham, 1955.

Horizon and locality.—Lower Cambrian limestones; Pelly Mountains, Quiet Lake Area, Yukon.

Discussion.—This specimen is tentatively placed in the genus *Ethmocoscinus* because of the nature of the inner wall and the presence of tabulae in the intervallum. The very wide intervallum and the much thickened, complicated vesicular inner wall may warrant erection of a new genus, at least a new species, but until more specimens can be studied to show that these characteristics are distinct and consistent, such a conclusion would be premature.

Family COSCINOCYATHIDAE Taylor, 1910
COSCINOCYATHUS DENTOCANIS Okulitch
Pl. 109, fig. 4–6

Coscinocyathus dentocanis Okulitch, 1943

Description.—This species is very common in the northern Cordilleran province of North America and was first discovered in the Dogtooth Range of Purcell Mountains, British Columbia. The original description of the species by Okulitch is as follows:

> The specimen is a naturally weathered out longitudinal section in light-grey limestone.
> *General Shape:* Tubular, with very slight taper. Reconstructed diameter must have been about 22 mm., and height about 60 or 70 mm., of which 50 mm. is visible. Width of intervallum is 5 mm. where diameter of central cavity is 12 mm., giving an intervallum coefficient of 5 mm.: 12 mm.
> *Outer Wall:* Probably thin and simple.
> *Intervallum:* Intervallum is crossed by radial vertical parieties and slightly convex upward tabulae. Resultant rectangular cells or loculi are about twice as high as wide; 14 parieties occur in space of 1 cm., giving parietal coefficient of about 4.5; tabulae are about 1.5 mm. apart.
> *Inner Wall:* Inner wall is apparently smooth and simple, without any structures projecting into central cavity.

The specimens of this collection agree closely in specifications to that of the original except that the partieties may be slightly thicker and fewer in number at a given diameter. The following measure-

ments are the average taken from the present collection:

Diameter	21–31	mm.
Diameter of central cavity	11–19	mm.
Width of intervallum	5– 7	mm.
Number of parieties	90	
Spacing of tabulae	1½	mm.
Intervallum coefficient	0.4	
Parietal coefficient	3.46	

The only addition which can be made to the original description is that *Coscinocyathus dentocanis* Okulitch appears to be generally elliptical in cross-section.

The small differences in parietal coefficient are not considered to be of specific importance.

Collection.—Geological Survey of Canada; collection nos. 24040 and 24041; specimen nos. 40-Y-4 G.S.C. No. 13327; 40-Y-6, G.S.C. no. 13328; and 41-Y-1. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

COSCINOCYATHUS MULTIPORUS, n. sp.
Pl. 109, fig. 7–9

General shape and size.—This species is based on a single large specimen which was 118 mm. long before it was cut. The specimen is partially weathered away, thus exposing a longitudinal section which shows numerous tabulae crossing the intervallum. The fossil is shaped like a large tapering cone. Dimensions, taken 35 mm. down from the larger end, are only approximate estimations because of the incomplete nature of the cup due to weathering.

Diameter	38	mm.
Diameter of central cavity	16	mm.
Width of intervallum	10	mm.
Number of parieties	100	
Spacing of tabulae	1–2	mm.
Intervallum coefficient	0.63	
Parietal coefficient	2.63	

Outer wall.—The outer wall appears to be thin, simple, and perforated by numerous pores, about 2 to 4 per intersept.

Intervallum.—The intervallum of the upper portion of the specimen is relatively wide with an intervallum coefficient of 0.63, but in the lower regions, the intervallum becomes extremely wide with its ratio to the central cavity equal to 7:4 or 1.75. It is crossed by very porous parieties and tabulae. The parieties, many of which are the short, interstitial type growing in from the outer wall, are thin, straight, radiating, and perforated by extremely fine pores closely spaced. In a random cross-section of a pariety, 22 or more may be present. Tabulae, also perforated by a great number of fine pores which produce a sieve-like appearance, are essentially horizontal and regularly spaced about 1 to 2 mm. apart.

Inner wall.—A slightly oblique, longitudinal thin section reveals clearly the pore pattern of the inner wall. Large, oblate, oval-shaped pores, which are as wide as the intersept and occur, arranged in a vertical series, 3 to 4 in number within the spacing of two tabulae, perforate the inner wall. The area of the void is, therefore, much greater than the area of the solid.

Collection.—Geological Survey of Canada; collection no. 24035. Holotype is marked 35-Y-13II, G.S.C. No. 13329. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—The exceedingly numerous fine pores of the parieties and tabulae, and the large pores of the inner wall are unlike the porous nature of any previously described species. Because the spitz of this specimen is missing, its nature is not known, but the smallest end present shows a very narrow central cavity and a wide intervallum crossed by very thick and bifurcated parieties.

COSINOCYATHUS CASSIARIENSIS, n. sp.
Pl. 109, fig. 10–13

General shape and size.—These specimens, approximately 40 to 50 mm. in length, are not complete archaeocyathids but are long, tubular shaped fragments. They are elliptical in cross-section. Specimen no. 35-Y-7 is taken as the holotype with dimensions as follows:

Diameter	15–20½	mm.
Diameter of central cavity	9–13	mm.
Width of intervallum	4	mm.
Number of parieties	75	
Spacing of tabulae	2	mm. or more
Intervallum coefficient	0.36	
Parietal coefficient	4.15	

The dimensions of no. 35-Y-9 are slightly larger, but its coefficients are almost iden-

tical with those of the holotype. Although no. 35-Y-8 has a relatively wide intervallum, it is included in this group because it is similar in general appearance.

Outer wall.—The outer wall is not preserved; consequently, no accurate description can be given. It is possible that the wall was thin and simple.

Intervallum.—The intervallum is crossed by numerous straight, radiating parieties and curved, net-like tabulae. The parieties may bifurcate, but are usually radial, straight, and perforated by many pores, up to ten in a random cross-section. The tabulae are arched, widely spaced, and perforated by many coarse pores which produce a sieve-like texture. The longitudinal section of no. 35-Y-7, showing structures better than the others, is not quite parallel to the central axis of the specimen. This fact, combined with the fact that the tabulae are not horizontal but dipping, accentuates the curved, irregular appearance of the tabulae.

Inner wall.—The inner wall is slightly thickened and perforated by large pores, about one to two per intersept. In vertical direction, they are spaced approximately 0.7 to 0.8 mm. apart.

Collection.—Geological Survey of Canada; collection no. 24035. Holotype is no. 35-Y-7, G.S.C. no. 13330; paratypes are nos. 35-Y-8, G.S.C. no. 1331 and 35-Y-9, G.S.C. no. 13332. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—The porous nature, the thick inner wall with almost canal-like pores, and the irregular, curved tabulae of this species distinguish it from other *Coscinocyathus.*

COSCINOCYATHUS INEQUIVALLUS, n. sp.
Pl. 110, fig. 1–6

General Shape and size.—Description is based on six long, cylindrical shaped specimens of which the longest was 45 mm. before it was cut The outer wall shows weak, regular, transverse annulations or constrictions where it is joined by the tabulae. Dimensions are as follows:

Diameter	10 –15 mm.
Diameter of central cavity	3 – 8 mm.
Width of intervallum	3½– 5 mm.
Number of parieties	55
Spacing of tabulae	1 – 2½ mm.
Average intervallum coefficient	0.72
Average parietal coefficient	4.45

Outer wall.—The outer wall is simple and appears to be perforated by large pores, but the pore pattern could not be determined. The wall is slightly constricted transversally at regular intervals where it is joined by the tabulae.

Intervallum.—The wide intervallum region is crossed by parieties and tabulae. The parieties are thick, straight, radiating, and perforated by small pores. Up to seven or

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EXPLANATION OF PLATE 109

FIG. *1*—*Ajacicyathus purcellensis* Okulitch. No. 36-Y-6, G.S.C. no. 13325, transverse thin section showing walls and parieties, ×1½.

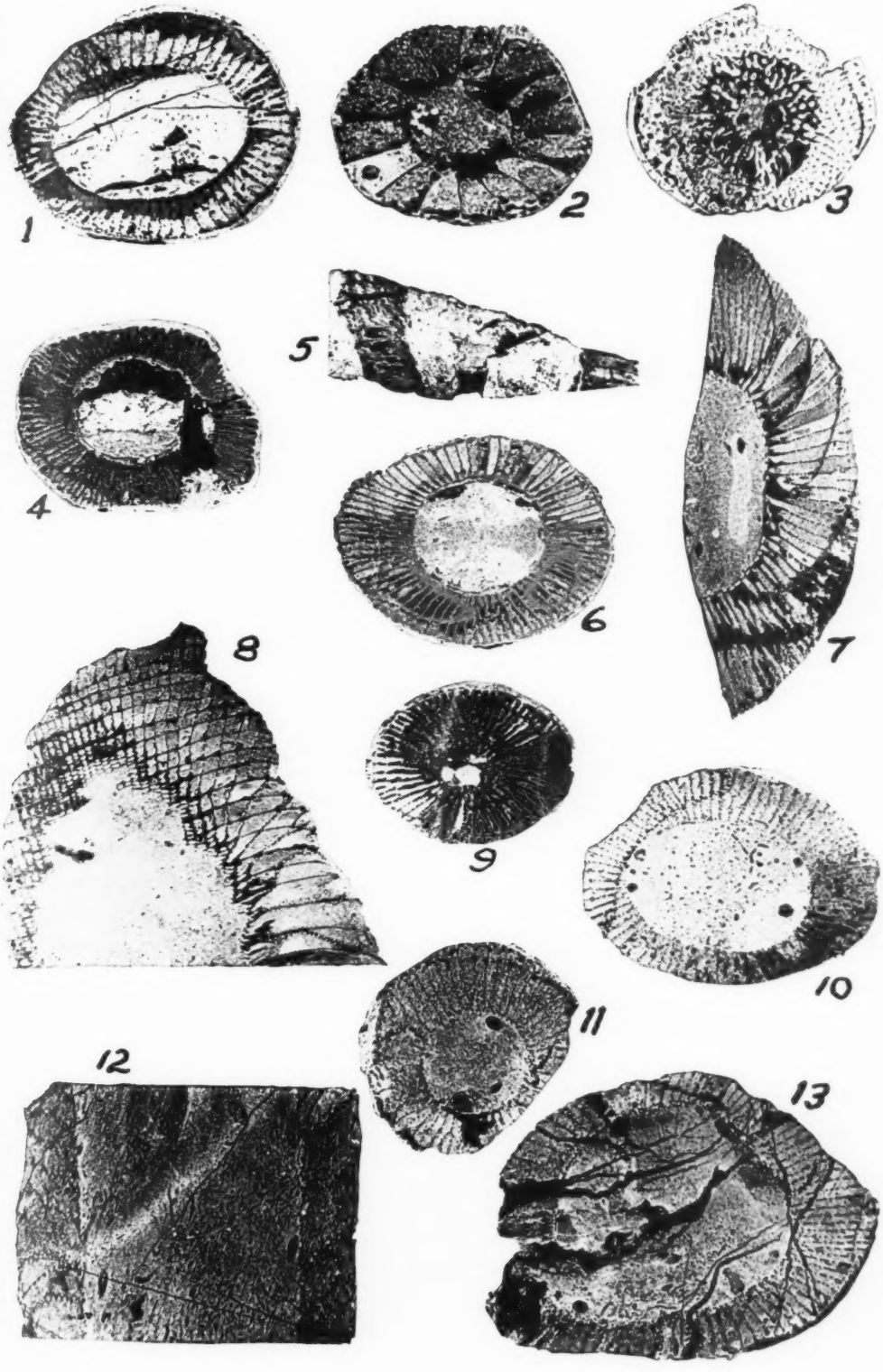
2—*Ajacicyathus yukonensis*, n. sp. Holotype, No. 35-Y-131, G.S.C. No. 13326, transverse thin section showing inner and outer walls and simple parieties, ×4.

3—*Ethmocoscinus sp.* No. AP-7, U.B.C., transverse thin section showing wide intervallum and thick, vesicular inner wall, ×1½.

4–6—*Coscinocyathus dentocanis* Okulitch. *4*, No. 40-Y-4, G.S.C. no. 13327, transverse thin section, ×1½. *5*, No. 40-Y-4, G.S.C. no. 13327, longitudinal thin section showing tabulae, ×1½. *6*,No. 40-Y-6, G.S.C. no. 13328, transverse thin section showing elliptical shape and simple radial parieties crossing the intervallum, ×1½.

7,9—*Coscinocyathus multiporus*, n. sp. *7*, holotype, No. 35-Y-1311, G.S.C. no. 13329, transverse thin section showing porous parieties and tabulae, ×1½. *8*, holotype ,No. 35-Y-1311, G.S.C. no. 13329, longitudinal thin section showing inner wall, parieties, and tabulae, ×1½. *9*, holotype, No. 35-Y-1311, G.S.C. no. 13329, transverse thin section, taken near the base of the specimen, showing narrow central cavity and thickened parieties, ×1½.

10–13—*Coscinocyathus cassiariensis*, n. sp. *10*, holotype, No. 35-Y-7, G.S.C. no. 13330, transverse thin section showing porous radial parieties, ×2. *11* paratype, No. 35-Y-8, G.S.C. no. 13331. Transverse thin section showing radial parieties, ×2. *12*, holotype, No. 35-Y-7, G.S.C. no. 13330, longitudinal thin section showing tabulae and parieties, ×2. *13*, paratype, No. 35-Y-9, G.S.C. no. 13332, transverse thin section of large fragmental specimen, ×2.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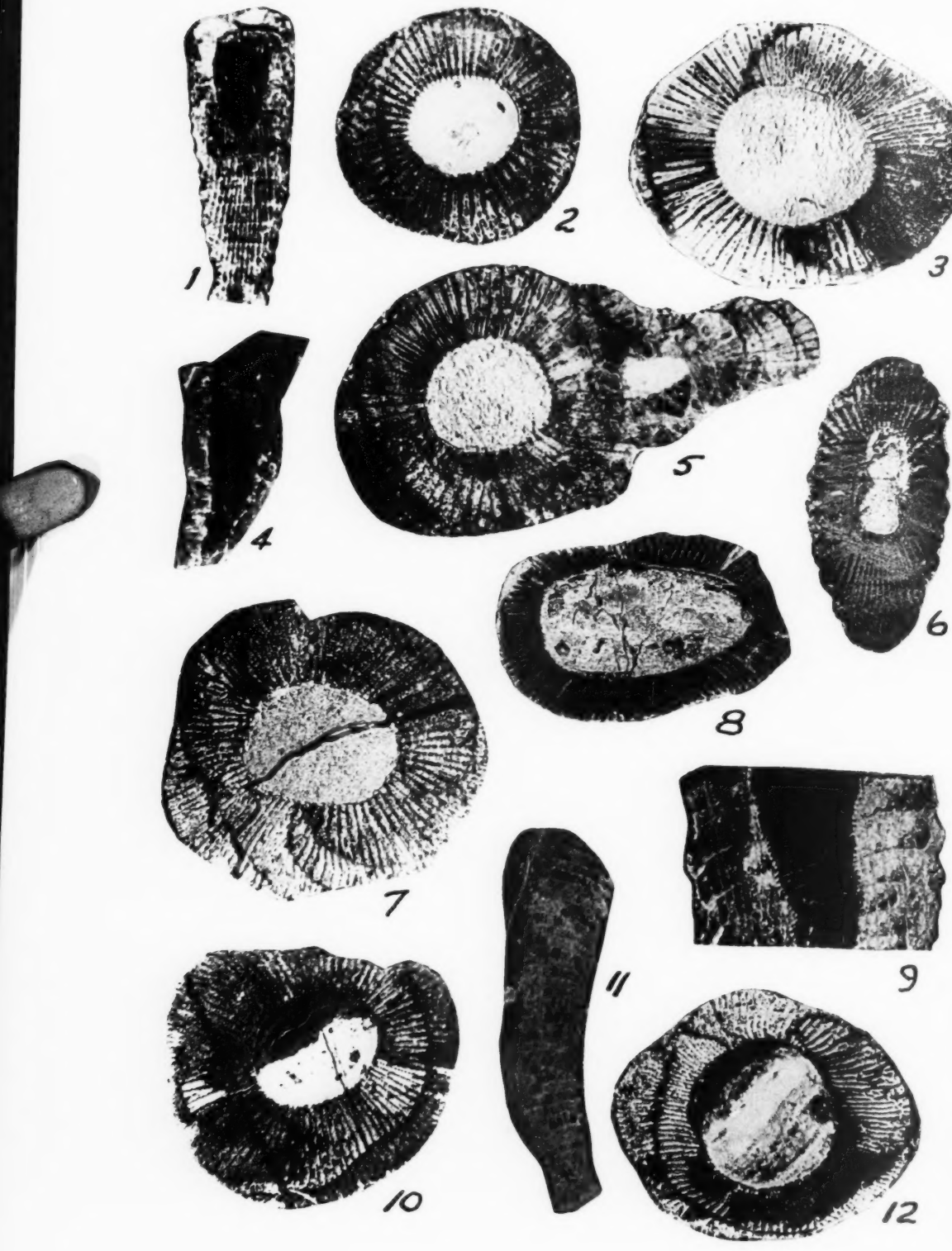
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eight pores have been counted in a random cross-section of a pariety. A few parieties bifurcate towards the outer wall, and in well preserved specimens, they appear to extend a short distance into the central cavity. Very finely porous tabulae, which cross the intervallum, are slightly curved convex-upward, and are spaced about 1 to 2½ mm. apart. The intersection of tabulae with parieties form rectangular loculi of which the height, in longitudinal section, is about 2 to 3 times the width.

Inner wall.—Like the outer wall, the inner wall is simple and perforated by large pores which appear to be one per intersept. However, parieties project a short distance from the inner wall into the central cavity, and in this respect the inner wall differs from the outer wall.

Collection.—Department of Geology, University of British Columbia. No. AP-14 is designated as the holotype; paratypes are nos. AP-13, 15, 16, 19, and 21. Collected by Aho and Padgham, 1955.

Horizon and locality.—Lower Cambrian limestone from Pelly Mountains, Quiet Lake Area, Yukon.

Discussion.—The intervallum and parietal coefficients of this species are almost identical with those of *Coscinocyathus equivallum* Taylor. They differ, however, in that the pores of this species are much coarser and that the parieties project into the central cavity making the inner wall dissimilar in appearance to the outer wall, hence the name *Coscinocyathus inequivallus* as opposed to *Coscinocyathus equivallum* Taylor.

The general appearance of *Coscinocyathus inequivallus*, n. sp., closely resembles *Coscinocyathus dentocanis* Okulitch, but is much smaller. The width of the intervallum to the diameter of the central cavity ratio is much larger, and the parieties appear to be thicker in this species.

Okulitch (1948) has described a *Coscinocyathus sp.* from the Dogtooth Range of British Columbia as follows:

> It is an acutely conical fragment exposing a pleosponge in a natural longitudinal section. The specimen is entirely recrystallized and no arching tabulae are visible. The intervallum coefficient is 4.6 or 0.6; the tabulae are spaced from 1½ mm. to 2 mm. apart. The total length of the specimen is 40 mm. and the maximum diameter is 14 mm. An exposed portion of the inner wall indistinctly shows numerous, crowded, very fine pores. The outer wall is worn smooth and does not show the pores. In one portion of the specimen are faintly visible thin straight parieties spaced about one-third of a millimeter apart. The poor preservation of the specimen does not permit its specific determination beyond the fact that it is a *Coscinocyathus* with elongated rectangular loculi.

This description seems to fit closely, except possibly for the inner wall, that of *Coscinocyathus inequivallus*, n. sp. Until better specimens can be found in the Donald Formation of the Dogtooth Range, or other localities, no definite conclusion can be

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EXPLANATION OF PLATE 110

FIG. *1–6*—*Coscinocyathus inequivallus*, n. sp. *1*, holotype, No. AP-14, U.B.C., longitudinal section showing tabulae, parieties, and central cavity, ×1.75. *2*, holotype, No. AP-14, U.B.C., transverse thin section showing radial parieties, tabulae, and inner wall, ×3. *3*, paratype, No. AP-13, U.B.C., transverse thin section, ×3. *4*, paratype, No. AP-19, U.B.C., longitudinal section showing parieties, ×1½. *5*, paratype, No. AP-15, U.B.C., transverse thin section of large specimen, and oblique section of smaller one showing tabulae, ×3. *6*, paratype, No. AP-16, U.B.C., oblique thin section showing weak annulation of outer wall, ×2.

7,9—*Coscinocyathus serratus*, n. sp., *7*, holotype, No. AP-17, U.B.C., transverse thin section showing radial parieties and complex inner wall, ×2. *9*, holotype, No. AP-17, U.B.C., Longitudinal section showing tabulae and inner wall, ×1.8.

Coscinosyathus veronicus, n. sp. Holotype, No. 40 Y-2, G.S.C. no. 13333, transverse thin section showing narrow intervallum and radial parieties, ×1½.

10,11—*Coscinocyathus tubicornus*, n. sp. *10*, holotype, No. 36-Y-11, G.S.C. no. 13334, transverse thin section showing wide intervallum and porous parieties, ×2. *11*, holotype, No. 36-Y-11, G.S.C. no. 13334, naturally weathered out specimen showing general form and tabulae, ×0.75.

12—*Coscinocyathus sp.* No. 36-Y-10, G.S.C. no. 13335, Transverse thin section showing delicate, radial parieties, and tabulae. Width of intervallum is about half the diameter of the central cavity, ×1½.

made as to whether *Coscinocyathus inequivallus*, n. sp., is a widely distributed species.

Coscinocyathus serratus, n. sp.
Pl. 110, fig. 7,9

General shape and size.—Description is based on a single specimen, AP-17, which was about 50 mm. in length before it was cut. It is a fragment of an acute conical cup with a slightly elliptical cross-section. The diameters of the lower, middle, and upper parts are 18, 23, and 28 mm., respectively. Weak, transverse annulations of the outer wall, similar to those of *Coscinocyathus inequivallum*, n. sp., are present. Complete dimensions of the upper, middle, and lower portions are as follows:

	Upper	Middle	Lower
Diameter	28 mm.	23 mm.	18 mm.
Diameter of central cavity	15 mm.	10 mm.	8 mm.
Width of intervallum	7–8 mm.	7 mm.	5 mm.
Number of parieties	105	80	70
Spacing of tabulae	3–3½ mm.	3–3½ mm.	3–3½ mm.
Intervallum coefficient	0.5	0.7	0.63
Parietal coefficient	3.75	3.5	3.9

Outer wall. Much of the outer wall has been replaced by calcite, but it appears to be thin, simple, and perforated by large pores. Pore arrangement could not be determined.

Intervallum.—The relatively wide intervallum region is crossed by a number of straight, radiating parieties which are perforated by a few small pores. An occasional pariety may bifurcate. Up-arching tabulae, perforated by numerous small circular pores, crossed the intervallum at relatively widely spaced intervals.

Inner wall.—The characteristic feature of this species is its inner wall. In transverse section, the inner wall, in part, appears thin, simple, and perforated by small pores, but in greater part, appears complicated by hook-like structures projecting into the central cavity. In longitudinal section, the hooked elements give the inner wall a serrated appearance. The inner wall structure of this species resembles that of Von Toll's *Archaeocyathus sibiricus* and Taylor's *Archaeocyathus wirrialpensis*.

Collection.—Department of Geology, University of British Columbia. Holotype is specimen AP-17. Collected by Aho and Padgham, 1955.

Horizon and locality.—Lower Cambrian limestone, Pelly Mountains, Quiet Lake Area, Yukon.

Discussion.—Superficially, this species resembles *Coscinocyathus inequivallus* n. sp. and *Coscinocyathus dentocanis* Okulitch, but it is much larger than the former. Its widely spaced tabulae and complicated inner wall distinguish it from previously described species.

Coscinocyathus veronicus, n. sp.
Pl. 110, fig. 8

General shape and size.—The shape of this species, judged from a fragment about 40 mm. long, is that of a gently tapering cone. In cross-section, it has an elliptical outline.

Diameter	20–30 mm.
Diameter of central cavity	12–21 mm.
Width of intervallum	5 mm.
Number of parieties	110
Spacing of tabulae	1– 1½ mm.
Intervallum coefficient	0.29
Parietal coefficient	4.4

Outer wall.—The outer wall appears to be thin and simple; the pore pattern is not clearly visible.

Intervallum.—The narrow intervallum region is crossed by straight, radiating parieties and closely spaced, finely porous tabulae. The parieties are perforated by a few fine pores and thickened by secondary calcite. Loculi are rectangular, slightly higher than wide.

Inner wall.—The inner wall, perforated by relatively large pores, appears to be very thin and simple. Because the specimen is not well preserved, the pore pattern could not be determined.

Collection.—Geological Survey of Canada; collection nos. 24040 and 24041. Holotype is marked 40-Y-2, G.S.C. no. 13333; paratypes are 41-Y-2 and 4. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's G4oup C sediments); Wolf Lake Area, Yukon.

Discussion.—This species is similar in parietal coefficient to *Coscinocyathus dentocanis* Okulitch, but differs in the intervallum coefficient and in the spacing of the tabulae. The almost quadrate loculi of this species resembles those of *Coscinocyathus rhyacoensis* Okulitch and *Coscinocyathus quadratus* Bedford and Bedford, but the new species differs from the latter two in the coefficients.

COSCINOCYATHUS TUBICORNUS, n. sp.
Pl. 110, fig. 10,11

General shape and size.—This species is represented by a single specimen, a slightly curved tubular form partially weathered out. Its diameter decreases from 21 to 12 mm. in a length of 60 mm. The lower portion is missing on this specimen. It is replaced to some extent by calcite, which obliterates the finer details of the skeleton.

Diameter	21 –22 mm.
Diameter of central cavity	8 – 9 mm.
Width of intervallum	6 – 7 mm.
Number of parieties	80
Spacing of tabulae	1½– 2 mm.
Intervallum coefficient	0.77
Parietal coefficient	3.81

Outer wall.—The outer wall appears thin and simple. The pore pattern cannot be determined from this specimen.

Intervallum.—The wide intervallum is crossed by parieties and tabulae. The parieties are thin, straight, radiating, and perforated by numerous fine pores. Tabulae, spaced about 1½ to 2 mm. apart, are porous mesh-like and slightly arched convex-upward.

Inner wall.—The inner wall is very thin, simple, and perforated by possibly two pores per intersept. The exact pore arrangement of the inner wall is not known. In part, the wall appears to be invaded and pushed in by foreign material, causing the parieties to project slightly into the central cavity.

Collection.—Geological Survey of Canada; collection no. 24036. Holotype is marked 36-Y-11, G.S.C. no. 13334. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group B sediments); Wolf Lake Area, Yukon.

Discussion.—The thin, simple, radiating parieties and closely set tabulae of this specimen place it in the genus *Coscinocyathus.* However, the wide intervallum, the narrow central cavity, and in the main, the general appearance of this species are quite different from those of the other species. *Coscinocyathus cylindricus* Bornemann and *Coscinocyathus tuba* Bornemann also have a wide intervallum, but in general appearance, this new species is quite unique.

COSCINOCYATHUS sp.
Pl. 110, fig. 12

General shape and size.—This species is represented by a very short fragment of a long cylindrical form. Because its general appearance is not known and much of the fossil in replaced by calcite, a specific determination can not be made.

Diameter	25–32 mm.
Diameter of central cavity	15 mm.
Width of intervallum	5– 9 mm.
Number of parieties	106
Spacing of tabulae	1– 1½ mm.
Intervallum coefficient	0.47
Parietal coefficient	3.72

Outer wall.—The outer wall is a simple thin mesh, perforated by fine pores.

Intervallum.—Extremely thin, radiating parieties perforated by very fine pores, and flat, closely spaced, net-like tabulae cross the intervallum region.

Inner wall.—The inner wall appears very thin and possibly perforated by numerous fine pores.

Collection.—Geological Survey of Canada; collection no. 24036. Specimen is marked 36-Y-10, G.S.C. No. 13335. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group B sediments); Wolf Lake Area, Yukon.

Discussion.—The general appearance and the salient features can not be determined on this small fragment, but the very thin and delicate nature of the walls and skeletal elements is the striking characteristic. The fineness of the skeleton resembles that of *Coscinocyathus tubicornus,* n. sp., but it differs in intervallum coefficient. If other specimens of the former can be found to show that larger diameters give smaller intervallum coefficients, then the specimen under consideration could certainly be

classified as *Coscinocyathus tubicornus*, n. sp.

The coefficients of this specimen are similar to those of *Coscinocyathus dentocanis* Okulitch, but in general appearance there seems to be no resemblance.

Carinacyathus perforatus, n. sp.
Pl. 111, fig. 1–5

General shape and size.—Naturally weathered out specimens of this species were up to 110 mm. long and tubular in shape before they were cut. In cross-section, they are elliptical. Specimen 35-Y-12, being the best preserved, was chosen as the holotype.

Diameter	21 –35	mm.
Diameter of central cavity	16	mm.
Width of intervallum	4 – 8	mm.
Number of parieties	100	
Spacing of tabulae	1½– 2½	mm.
Intervallum coefficient	0.38	
Parietal coefficient	3.57	

Outer wall.—The outer wall is not well preserved, but appears to be thin, simple, and perforated by numerous small pores. The pore pattern is not known.

Intervallum.—The intervallum is crossed by numerous straight, radiating parieties and by weakly up-arched tabulae. The parieties, spaced about 0.8 mm. apart, are perforated, in a random cross-section, by twelve or more very fine pores about 0.1 mm. in diameter. The tabulae, spaced 1½ to 2½ mm. apart, are perforated by numerous fine pores, resulting in a fine meshed net. The intersection of tabulae with parieties form rectangular loculi, which are about twice as high as they are wide.

Inner wall.—The most characteristic feature of this species is its inner wall. It is composed of continuous annular, sigmoidally curved plates spaced about 0.5 mm. apart in longitudinal direction. They project about 0.3 to 0.4 mm. into the central cavity and line it with horizontal annular shelves.

Collection.—Geological Survey of Canada; collection no. 24035. Holotype is no. 35-Y-12, G.S.C. no. 1336; paratypes are nos. 35-Y-6 and 35-Y-10, G.S.C. no. 13337. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—These specimens, with well developed tabulae and straight, radiating parieties, undoubtedly belong to the family Coscinocyathidae Taylor and are classified as genus *Carinacyathus* Vologdin because of their complex inner wall. The Bedfords (1936a) have described a new genus *Sigmocoscinus* with *Sigmocoscinus sigma* Bedford & Bedford as genotype. The coefficients and and description of the skeletal structure, except for the outer wall, closely resemble those of *Carinacyathus perforatus*, n. sp. The outer wall of *Sigmocoscinus sigma* is described as follows by Bedford & Bedford:

> outer wall-pores are small, about 4 to one mm., about three rows to each intersept, and are covered externally by overlapping annular plates, about 4 of these occurring in each mm. of length.

An outer wall, composed of sigmoidal annular plates, is not present on these specimens, perhaps the result of poor preservation. If this is the case, then the fossils here described are *Sigmocoscinus sigma*.

Genus *Carinacyathus* includes all Coscinocyathidae with complex inner walls, irrespective of the nature of the outer wall. Hence, if better specimens can be found from the same locality to prove that these specimens are conspecific with *Sigmocoscinus sigma*, then they should be classed as *Carinacyathus sigma* (Bedford & Bedford).

Carinacyathus perforatus, n. sp., closely resembles *Coscinocyathus dentocanis* Okulitch but it differs in the nature of the inner wall.

Specimen no. 35-Y-10 is similar to the holotype, except that it has a larger central cavity. The inner wall is complicated by elements projecting into the cavity region, but the arrangement is not clearly visible; therefore specimen 35-Y-10 is provisionally classed as *Carinacyathus perforatus*, n. sp.

Occurrences of this genus have been reported from Siberia and Australia but this is its first occurrence in North America.

Order Metacyathida Bedford & Bedford 1936

Family Archaeocyathidae Taylor, 1910

Archaeocyathus *cf.* A. atlanticus Billings
Pl. 111, fig. 6,7

Archaeocyathus atlanticus Billings, 1861

General shape and size.—The specimen is a large, flattened archaeocyathid about 135 mm. long. It is conceivable that it was originally long, acute conical in form with an elliptical cross-section. Because of extreme

deformation and the partially weathered away condition at the upper end, dimensions are only extimates.

	Upper	Lower
Diameter	44 mm.	30 mm.
Diameter of central cavity	15 16 mm.	9 mm.
Width of intervallum	9–18 mm.	5–15 mm.
Intervallum coefficient	0.87	0.94

Outer wall.—Due to replacement by calcite and to weathering away, the characteristic of the outer wall cannot be readily seen. It appears to be thin and delicate, but no pore arrangements are known.

Intervalum.—The intervallum is relatively wide with an intervallum coefficient of about 0.9, which is identical with that of the original Geological Survey of Canada holotype no. 369 described by Billings in 1861. The intervallum is crossed, in part, by wavy parieties and, in part, by irregular taeniae and synapticulae. In the lower portions, taeniae are bifurcated, anastomosed, and perforated by large pores, and appear to be thickened.

Inner wall.—Poor preservation makes it possible to see the exact nature of the inner wall, but it appears to be slightly thicker than the outer wall. The pore pattern could not be determined.

Collection.—Geological Survey of Canada; collection no. 24035, specimen no. 35-Y-14, G.S.C. No. 13339. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—A definite identification cannot be made because of poor preservation and extreme deformation of the original general appearance. The intervallum coefficient and the irregular nature of the intervallum skeletal elements of this specimen resemble those of *Archaeocyathus atlanticus* Billings. Until better and more revealing specimens of this archaeocyathid are made available, a new species will not be erected.

ARCHAEOCYATHUS (?) sp.
Pl. 111, fig. 8

General shape and size.—This specimen is a fragment about 30 mm. long, of a large conical shaped cup with an elliptical cross section. It is cut by calcite stringers and much of the fossil is replaced by carbonate.

Diameter	35–41 mm.
Diameter of central cavity	16–21 mm.
Width of intervallum	8–10 mm.
Intervallum coefficient	0.49

Outer wall.—The outer wall appears thick, simple and possibly perforated by fine pores.

Intervallum.—The intervallum is crossed by irregular bifurcating and anastomosing taeniae, and in part by wavy *Pycnoidocyathus*-type parieties. Parieties and teaniae are thick and perforated by large pores.

Inner wall.—The inner wall is slightly thicker than the outer wall, but the replacement by calcite makes the determination of the pore pattern impossible.

Collection.—Geological Survey of Canada; collection no. 24041; specimen no. 41-Y-3, G.S.C. no. 13340. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—The intervallum is crossed in part by thick wavy parieties as found in *Pycnoidocyathus*, and in part by irregular taeniae characteristic of *Archaeocyathus*. In general appearance, the intervallum, in both transverse and longtitudinal view, resembles that of the latter. The classification, beyond the fact that it belongs to the order Metacyathida, is not definite and no specific determination is possible from this fragment.

Family PYCNOIDOCYATHIDAE Okulitch, 1950
PYCNOIDOCYATHUS AMOURENSIS (Okulitch)
Pl. 112, fig. 1

Cambrocyathus amourensis Okulitch, 1943

General shape and size.—In the Yukon collections, this common Labrador species is represented by a single small fragment. The general shape cannot be determined from this small piece, but the dimensions are as follows:

Diameter	20	mm.
Diameter of central cavity	5	mm.
Width of intervallum	7	mm.
Number of parieties	36	
Intervallum coefficient	1.4	
Parietal coefficient	1.8	

Discussion.—The salient features of the outer and inner walls are obliterated by calcite recrystallization. The narrow central cavity and the nature of the intervallum are

definitely related to *Pycnoidocyathus amourensis* (Okulitch) but the general shape, which is the main criterion used in identification of this species, is not known for the specimen under discussion. The low parietal coefficient is not of specfic importance because even in the holotype, the coefficient varies to some extent at different diameters.

Collection.—Geological Survey of Canada; collection no. 24036; specimen no. 36-Y-9, G.S.C. no. 13341. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group B sediments); Wolf Lake Area, Yukon.

PYCNOIDOCYATHUS COLUMBIANUS
(Okulitch)
Pl. 112, fig. 2

Cambrocyathus amourensis Okulitch, 1943

General shape and size.—Description is based on two specimens which are short fragments of large, conical cups. Largest specimen is about 70 mm. in diameter and 60 mm. in length, which is too short to show annulations of the outer wall.

Diameter	65–70 mm.
Diameter of central cavity	34–36 mm.
Width of intervallum	16–18 mm.
Number of parieties	90
Intervallum coefficient	0.48
Parietal coefficient	1.35

Outer wall.—The nature of the outer wall of these specimens is indeterminable because parieties diffuse out into the limestone matrix leaving no wall visible.

Intervallum.—The relatively wide intervallum is crossed by numerous thin, wavy, perforated parieties. Radiating parities, supplied with abundant synapticulae, are slightly thickened near the inner wall.

Inner wall.—The inner wall is slightly thickened and perforated by large pores but pore pattern could not be determined. Thickening of the inner wall and of the parieties where they join the inner wall may be due to replacement by calcite.

Collection.—Department of Geology, University of British Columbia; specimens AP-22 and 23. Collected by Aho and Padgham, 1955.

Discussion.—These specimens are identified as *Pycnoidocyathus columbianus* (Okulitch) on general appearance and intervallum characteristics. They are very similar to *Pycnoidocyathus columbianus* from the McDame Area described by Okulitch (1955). The McDame specimens have a fairly constant intervallum coefficient between 0.41 and 0.45, but the parietal coefficient of these specimens is not of specific importance. These specimens are closely related to *Pycnoidocyathus occidentalis* (Okulitch) in size and shape but the latter has a much higher intervallum coefficient.

PYCNOIDOCYATHUS *cf.* P. OCCIDENTALIS
(Okulitch)
Pl. 112, fig. 3–6

Cambrocyathus occidentalis Okulitch, 1943

General shape and size.—This species, a large, conical, expanding form, is represented in the Geological Survey of Canada collection by specimens approximately 130 mm. long. The lower portion of the cone is weakly to strongly annulated transversally, but annulations are not prominent or are completely lacking in the upper parts. Dimensions of the larger end are, on the average, as follows:

Diameter	55.65 mm.
Diameter of central cavity	25–32 mm.
Width of intervallum	18 mm.
Number of parieties	120
Intervallum coefficient	0.63
Parietal coefficient	2.0

Towards the apex of the cone, the diameter of the central cavity, width of the intervallum, and the number of parieties decrease correspondingly with the decrease in diameter of the outer cone. The transverse annulations of the walls near the base cause some variations in the coefficients; the intervallum coefficients ranging from 0.60 to 1.0 with an extreme case of 0.43, and the parietal coefficients, from 1.3 to 2.0.

Outer wall.—The poor preservation of the outer wall makes the determination of its pore pattern impossible. The outer wall is transversally annulated at the smaller end of the cone.

Intervallum.—The wide intervallum is crossed by wavy to bifurcating parieties which are perforated by numerous pores and supplied with abundant synapticulae. Parieties are relatively thickened towards the inner wall.

Inner wall.—Near the upper end of the organism, the inner wall appears to be thin, simple, and perforated by pores. Pore characteristics could not be determined because of calcite replacement. In the lower end, the inner wall appears to be complicated by irregular, transverse annulations and is perforated by numerous fine pores which give a serrated effect to the wall in random sections.

Collection.—Geological Survey of Canada; collection no. 24036. Specimen nos. 36-Y-1, G.S.C. no. 13345; 36-Y-2, G.S.C. no. 13344; 36-Y-3, G.S.C. no. 13343; 36-Y-12, G.S.C. no. 13342. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group B sediments); Wolf Lake Area, Yukon.

Discussion.—The intervallum and parietal coefficients, size, and general appearance of these specimens are almost identical to specifications of the holotype described by Okulitch (1953). Specimen no. 36-Y-3 of this collection shows irregularities and numerous perforations of the inner wall towards the smaller end but replacement by calcite obliterates some of the finer details. This species is related to *Pycnoidocyathus columbianus* (Okulitch) but has a much larger intervallum coefficient.

PYCNOIDOCYATHUS *cf.* P. DISSEPIMENTALIS (Okulitch)
Pl. 112, fig. 7

Cambrocyathus dissepimentalis Okulitch, 1943

General shape and size.—True shape of the cup can not be given accurately from the two fragments here described, but they appear to be tapering conical cups. Longitudinal sections show very shallow transverse annulations of the outer wall.

Diameter	35 mm.
Diameter of central cavity	14–16 mm.
Width of intervallum	7– 8 mm.
Number of parieties	75
Intervallum coefficient	0.5
Parietal coefficient	2.14

Outer wall.—The outer wall is not preserved. The outer wall of the holotype from Labrador is described by Okulitch (1943) as follows:

> *Outer Wall:* Of average thickness, penetrated by numerous fairly large pores. Some of the pores open directly into interparietal spaces; others open into oblique canals penetrating wall at an angle. In some cases a cluster of pores appears to open into same canal. Wall is crenulated by transverse bulges, as is typical of the genus. Spacing of the bulges is about 5 or 6 mm.

Intervallum.—The most characteristic feature of this species is the intervallum region. It is completely filled with dissepimental tissue and synapticulae, and is crossed by relatively thin, wavy radiating parieties which occasionally bifurcate. The parieties are very porous, with eight or more pores visible in random cross section, and about seven in five millimeters of a longitudinal section.

Inner wall.—In oblique section, the inner wall appears as a thin, finely porous mesh. No definite pore pattern could be seen in these specimens, but it appears irregular.

Collection. Department of Geology, University of British Columbia; specimen nos. AP-23 and 24. Collected by Aho and Padgham, 1955.

Discussion.—These specimens are compared with *Pycnoidocyathus dissepimentalis* (Okulitch) because of the dense tissue fillings of the intervallum. The coefficients of these specimens are nearly the same as that of the holotype, but parieties are thinner and more porous. These slight differences may not be of specific importance to justify erection of a new species.

PYCNOIDOCYATHUS SOLIDUS, n. sp.
Pl. 112, fig. 8,9

General shape and size.—Description is based on a single specimen about 37 mm. long. The cup is conical in shape, the larger end averaging 34 mm. in diameter and the smaller end, 25 mm. The lower portion of the cone is missing. The dimensions of the upper elliptical cross-section are as follows:

Diameter	28–39 mm.
Diameter of central cavity	7 mm.
Width of intervallum	10–18 mm.
Number of parieties	67
Intervallum coefficient	2.0
Parietal coefficient	1.97

Outer wall.—The outer wall appears to be thin, simple, and perforated by one or two large pores per intersept. The walls are thickened by calcite replacement.

Intervallum.—The very wide intervallum and the extremely narrow central cavity are the most noteworthy features of this species. The intervallum is crossed by relatively

thick, wavy parieties which are penetrated by a few small pores. The parieties bifurcate and anastomose toward the outer wall but are straight and closely crowded near the inner wall. They are supplied with occasional synapticulae.

Inner wall.—Another characteristic feature of this species is its inner wall. At the larger diameter, the wall appears to be thin, simple, and possibly perforated by small pores. Towards the base, the inner wall is thickened considerably and penetrated by large canal-like pores. The central cavity here is indefinable because it is completely filled with irregular extraneous rod-like material.

Collection.—Geological Survey of Canada; collection no. 24040. Holotype is marked 40-Y-7, G.S.C. no. 13346. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—The generic classification of this specimen is uncertain because many of its features seem to resemble *Pycnoidocyathus* as well as *Metaldetes* and *Paranacyathus*. The central cavity, filled with trabecular elements, shows affinity to the last two genera, but this specimen is classed as *Pycnoidocyathus* because of its relatively regular but wavy parieties characteristic of this species.

Although no conclusions can be made here, there is a possibility that either or both *Metaldetes* and *Paranacyathus* could be classed with the genus *Pycnoidocyathus*.

The extremely wide intervallum, narrow central cavity which is undefinable at the base, and the thick wavy parieties are the main features of the species. The narrow central cavity resembles that of *Pycnoidocyathus amourensis* (Okulitch) but they differ radically in general appearance.

Loculicyathus ellipticus, n. sp.
Pl. 113, fig. 1–6

General shape and size.—The specimens are tapering, conical cups about 60 to 70 mm. long on the average, but specimen no. 35-Y-2 was 130 mm. in length before it was cut. They are elliptical in cross section. The average dimensions are:

Diameter	20 mm.
Diameter of central cavity	10 –11 mm.
Width of central cavity	4½– 5½ mm.
Number of parieties	55 –65
Intervallum coefficient	0.45–0.55
Parietal coefficient	2.75–3.25

Specimen 35-Y-2 is much larger, but the diameter and coefficients taken at midpoint of length are comparable to dimensions of the others. At the upper end of this specimen, where the diameter is 24 by 34 mm., the intervallum is very narrow, giving an intervallum coefficient of 4½:19 or 0.24. This variation of the coefficient, even within a single, long, conical specimen, throws doubt on the validity of the coefficient as a criterion for classifying species. Another peculiar feature of this specimen is that in the upper regions, part of its intervallum is filled with dense vesicular tissue while other parts are not. It is not known whether this

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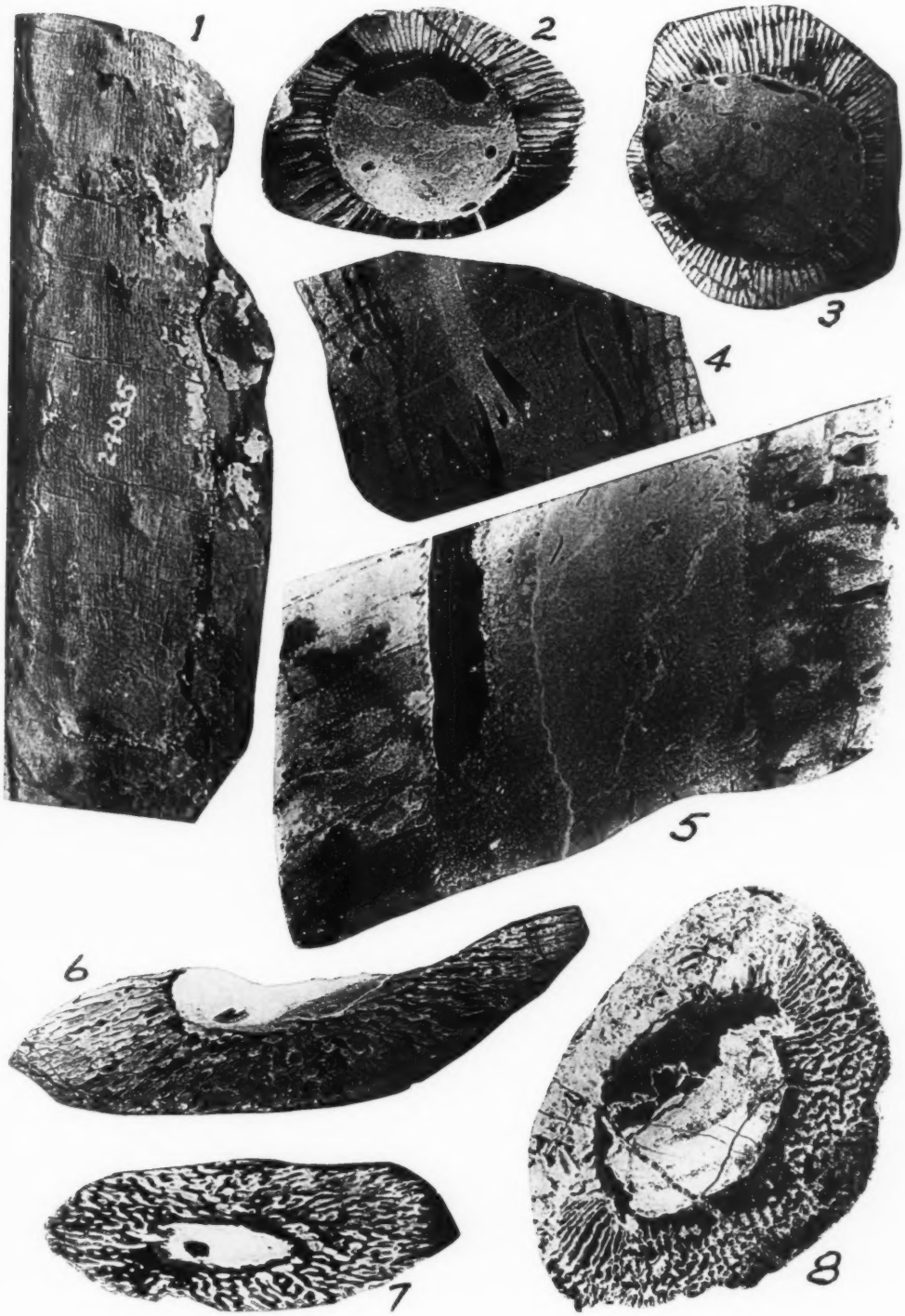
Explanation of Plate 111

Fig. *1–5*—*Carinacyathus perforatus*, n. sp. *1*, holotype, No. 35-Y-12, G.S.C. no. 13336, naturally weathered out specimen, ×1. *2*, holotype, No. 35-Y-12, G.S.C. no. 13336, transverse thin section showing radial parieties and porous tabulae crossing the intervallum, ×1½. *3*, paratype, No. 35-Y-10, G.S.C. no. 13342, transverse thin section showing parieties and tabulae crossing the intervallum, ×1½. *4*, paratype, No. 35-Y-10, G.S.C. no. 13337, longitudinal thin section showing tabulae, parieties, and inner wall, ×1½. *5*, holotype, No. 35-Y-12, G.S.C. no. 13338, longitudinal thin section showing complex inner wall, and perforated parieties and tabulae, ×3.

6–7—*Archaeocyathus cf. atlanticus* Billings. *6*, No. 35-Y-14, G. S. C. no. 13339, transverse thin section, taken from the upper portion of the specimen, showing intervallum, ×1½. *7*, No. 35-Y-14, G.S.C. no. 13339, transverse thin section taken from near the base of the specimen; intervallum of flattened specimen is filled with irregular wavy taeniae, ×1½.

8—*Archaeocyathus (?) sp.* No. 41-Y-3, G.S.C. no. 13340, transverse thin section showing intervallum crossed, in part, by irregular taeniae, and in part, by wavy parieties; much of the intervallum region is replaced by calcite, ×1½.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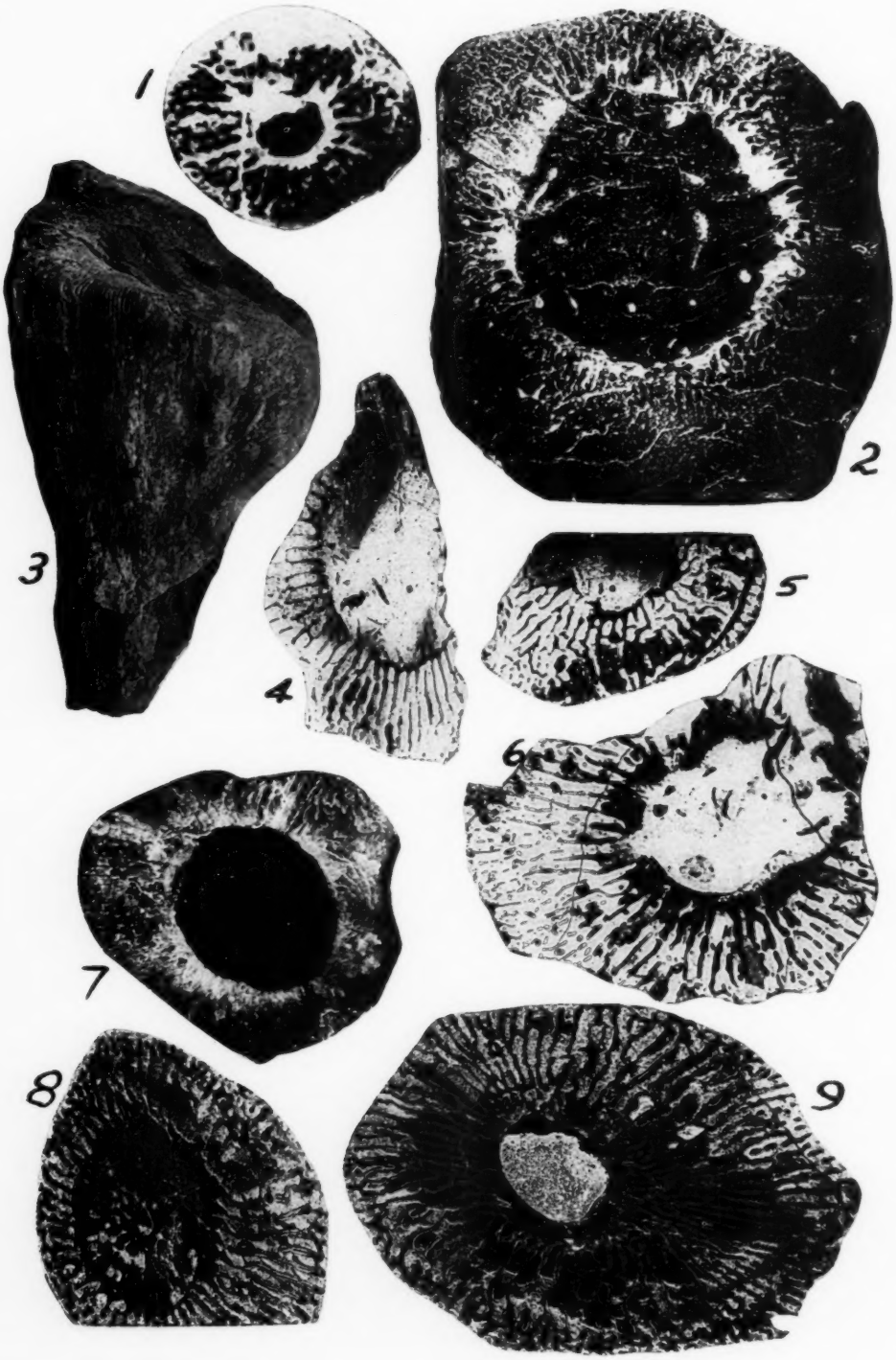
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is due to preservation or to parasitic or symbiotic activities. The bottom 20 mm. of this specimen is bent at right angles to the axis of the main cone, indicating that this animal had an accident during its life history.

Outer wall.—Much of the outer wall is worn away, but poorly preserved parts indicate a thin, simple, perforated wall. The pore pattern is not known

Intervallum.—The most characteristic feature of this species is its intervallum region. It is crossed by coarsely perforated, straight, radial parieties and is completely filled with vesicular tissue (except upper portions of 35-Y-2). Vesicles are obliquely elongated. The parieties can be seen distinctly even within the vesicular mass.

Inner wall.—The inner wall is simple and has about the same thickness as the parieties. The wall is perforated by one or two coarse pores per intersept.

Collection.—Geological Survey of Canada; collection no. 24035. Holotype is 35-Y-1, G.S.C. no. 13347; paratypes are 35-Y-2, G.S.C. no. 13348; 35-Y-3, G.S.C. no. 13349; and 35-Y-4, 5 and 11. Collected by W. H. Poole, 1953.

Discussion.—Genus *Loculicyathus* was first found in Siberia and described by Vologdin (1931). These specimens are the first to be found outside of Siberia and are different from the Siberian species. In transverse section, *Loculicyathus ellipticus*, n. sp., looks much like *Metacoscinus deasensis* Okulitch in its coarsely perforated radial walls and intervallum of dense vesicular and dissepimental tissues. They differ in that the former has no tabulae.

Family METACOSCINIDAE Bedford & Bedford, 1932

METACOSCINUS POOLENSIS, n. sp.

Pl. 113, fig. 7–11

General shape and size.—This species is represented by four long, tapering conical fragments. They are elliptical in cross-section. The largest fragment is crenulated at the top and is 45 mm. in length, but it could easily have been two or three times as long.

Diameter	28–34 mm.
Diameter of central cavity	14–20 mm.
Width of intervallum	8 mm.
Number of parieties	80
Spacing of tabulae	1–1½ mm.
Intervallum coefficient	0.47
Parietal coefficient	2.6

The above are average measurements of the larger end of the specimens. Towards the base, width of the intervallum does not decrease correspondingly, giving a higher intervallum coefficient.

Outer wall.—The outer wall is marked with gentle, transverse annulations where the wall is joined by the tabulae. The wall appears to be thin, delicate, and perforated by fine pores, up to six per intersept. The walls being poorly preserved, exact determination of the pore pattern is impossible.

Intervallum.—The presence of tabulae, parieties, and vesicular tissues is the characteristic feature of the relatively wide intervallum region. The parieties, supplied

EXPLANATION OF PLATE 112

FIG. *1*—*Pycnoidocyathus amourensis* (Okulitch). No. 36-Y-9, G.S.C. no. 13341, cross-section showing wide intervallum; inner wall is replaced by calcite; ×2.

2—*Pycnoidocyathus columbianus* (Okulitch). No. AP-22, U.B.C., cross-section showing wavy parieties with synapticulae, ×1.

3–6—*Pycnoidocyathus cf. occidentalis* (Okulitch). *3*, No. 36-Y-12, G.S.C. no. 13342, naturally weathered out conical-shaped specimen, ×0.6. *4*, No. 36-Y-3, G.S.C. no. 13343, transverse thin section showing radial parieties with synapticulae, ×1½. *5*, No. 36-Y-2, G.S.C. no. 13344, transverse thin section, taken from near the base, showing narrower central cavity, ×1½. *6*, No. 36-Y-1, G.S.C. no. 13345, transverse thin section showing varieties and pores of inner wall, ×1½.

7—*Pycnoidocyathus cf. dissepimentalis* (Okulitch). No. AP-25, U.B.C., cross-section showing parieties and dissepiments, ×1.25.

8–9—*Pycnoidocyathus solidus*, n. sp. *8*, holotype, No. 40-Y-7, G.S.C. no. 13346, transverse thin section, taken from near the base of the specimen, showing nature of central cavity, ×2. *9*, holotype, No. 40-Y-7, G.S.C. no. 13346, transverse thin section showing narrow central cavity, and wide intervallum crossed by wavy parieties with synapticulae, ×2.

with few synapticulae, are thin, straight, radiating and occasionally bifurcating. They seem to be almost imperforate and to project a short distance into the central cavity. Tabulae, spaced about 1 to 1½ mm. apart, are perforated by extremely fine, closely set pores. Towards the smaller diameter, the intervallum region becomes filled with very fine vesicular dissepimental tissue. The upper regions and the central cavity appear to be free of this tissue.

Inner wall.—Features of the inner wall are not clear, but the wall appears to be invaded and pushed in by foreign material. The wall is thin and perforated by large pores which lead into the loculi. Very thin parieties project into the central cavity, but the cavity is free of other elements.

Collection.—Geological Survey of Canada; collection no. 24040. Holotype is 40-Y-5, G.S.C. no. 13350; paratypes are 40-Y-1, G.S C. no. 13352; and 40-Y-3, G.S.C. no. 13351. Collected by W. H. Poole, 1953.

Horizon and locality.—Lower Cambrian (Lord's Group C sediments); Wolf Lake Area, Yukon.

Discussion.—The radial parieties, tabulae, and vesicular tissue in the intervallum indicate that these specimens belong to genus *Metacoscinus*, but the imperforate nature of the parieties is not typical of this genus. This fact is not considered to be of generic importance. This species resembles *Metacoscinus deasensis* Okulitch, but differs in the nature of the parieties and the intervallum coefficient.

The specific name is proposed in honour of Dr. Poole of the Geological Survey of Canada.

METACOSCINUS sp.
Pl. 113, fig. 12

General shape and size.—This species is represented by a single poorly preserved conical fragment about 25 mm. long.

Diameter	18	mm.
Diameter of central cavity	6	mm.
Width of intervallum	6	mm.
Number of parieties	42	
Spacing of tabulae	?	
Intervallum coefficient	1.0	
Parietal coefficient	2.3	

Outer wall.—The outer wall is simple and perforated by large pores. The pore pattern could not be determined.

Intervallum.—The intervallum width is equal to the diameter of the central cavity. The intervallum is crossed by regular, wavy parieties which are perforated by pores and supported by synapticulae. In transverse thin-section, porous tabulae can be seen, but the spacing of the tabulae could not be determined in longitudinal section.

Inner wall.—The inner wall is simple, slightly thickened, and perforated by large pores. The pore pattern is not known.

Collection.—Department of Geology, University of British Columbia; specimen no. AP-6 Collected by Aho and Padgham, 1955.

Horizon and locality.—Lower Cambrian limestone; Pelly Mountains, Quiet Lake Area, Yukon.

Discussion.—This specimen is provisionally assigned to the genus *Metacoscinus*, but its specific name is not determined. The parietal and intervallum coefficients are different from the coefficient of known species.

CLARUSCYATHUS KETZAENSIS, n. sp.
Pl. 113, fig. 14–16

General shape and size.—The specimens are small horn-shaped fragments, the largest being about 35 mm. long. The tips on some are sharply curved. Few show weak transverse annulations. The average measurements are:

Diameter	18	mm.
Diameter of central cavity	5½	mm.
Width of intervallum	6½	mm.
Number of parieties	40?	
Spacing of tabulae	1–2	mm.
Intervallum coefficient	1.2	
Parietal coefficient	2.4?	

Outer wall.—The outer wall is relatively thick and perforated by large canal-pores. The arrangement of the pores is not known.

Intervallum.—The very wide intervallum region is the most characteristic feature of this species, giving an intervallum coefficient of 1.2. It is also filled with extremely coarse, curving and branching taeniae. These structural elements start out as parieties from the inner wall but break up into irregular elements as they extend out into the intervallum. The intervallum is crossed by porous, up-arching tabulae 1 to 2 mm. apart. In longitudinal section, the tabulae can be seen to depart horizontally from the inner wall. The tabulae abut the outer wall at an acute angle.

Inner wall.—The inner wall is thickened considerably and penetrated by coarse oblique pore-canals. In transverse section, the inner wall appearance approaches the vesicular inner wall of *Ethmophyllum*.

Collection.—Department of Geology, University of British Columbia. Specimen AP-2 is designated as the holotype. Paratypes are AP-1, 3, 4, 81, 811, 8, 10 and 11. Collected by Aho and Padgham, 1955.

Horizon and Locality.—Lower Cambrian limestone; Pelly Mountains, Quiet Lake Area, Yukon.

Discussion.—This species is closely related to *Eucyathus obliquus* Okulitch from the Dogtooth Mountains, B.C. It differs in that the latter has *Pycnoidocyathus*-type parieties, while this has irregular *Archaeocyathus*-type parieties. The skeletal structure of *Claruscyathus ketzaensis*, n. sp., is unique.

AFFINITIES TO OTHER FAUNAE

Six families, the Ajacicyathidae, the Ethmophyllidae, the Coscinocyathidae, the Archaeocyathidae, the Pycnoidocyathidae, and the Metacoscinidae of the Phylum Archaeocyatha are represented in the fossil collections from the Yukon. In all, twenty-three species, of which twelve are new, are here described. The Yukon fauna is dominated by *Coscinocyathus* and *Pycnoidocyathus*.

The dominance of *Coscinocyathus* and *Pycnoidocyathus*, which is characteristic of faunas to the south in British Columbia, suggests that the Yukon fauna has affinities with the faunas in British Columbia. The presence of *Coscinocyathus dentocanis* Okulitch, *Pycnoidocyathus columbianus* Okulitch, and *Ajacicyathus purcellensis* Okulitch shows close relationship among the faunas. *Metacoscinus*, which is a common genus in the McDame collection, is also present in the collections studied. The occurrence of *Loculicyathus* and *Carinacyathus* suggests relationship between this fauna and the Siberian and Australian faunas. There appears to be a complete lack of relationship between the Yukon fauna and the California-Nevada faunas, which are dominated by Ethmophyllidae.

It was surprising to find a large number of new species in the collections. The fossil localities in the Yukon are only two to three hundred miles northwest of the McDame locality of British Columbia. Similar species were therefore expected, but in this distance a great number of new species become present. Archaeocyathids are very abundant in the Yukon and every new collection seems to produce new species.

AGE OF THE ROCKS

Archaeocyathids in Lord's (1944) Groups B and C sediments definitely date the rocks, in part, as upper Lower Cambrian. The relative age relation between Groups B and C was not known to Lord, but it can now be asserted positively that both groups contain fossiliferous zones of the same age.

The rock groups defined by Lord are large and may contain a number of units. Poorly preserved fossils suggestive of crinoid stems and cup corals were found in Groups B and C sediments, respectively. Lord, therefore, suggested that Group C may be of Carboniferous? age. It is quite possible that these large groups contain strata of different ages, certainly rocks of early Cambrian age.

Sedimentary rocks at the headwaters of the Ketza River in the Pelly Mountains are also of upper Early Cambrian age. The regional geology of this area is largely unknown, but the rocks here are probably a continuation of the Lower Cambrian rocks exposed in the Wolf Lake Area 120 miles to the southeast. It is apparent that a large area in the Yukon is underlain by Lower Cambrian Rocks.

Well preserved Lower Cambrian archaeocyathids, Ordovician graptolites, and Palaeozoic corals were collected by H. Trettin in the Pelly Mountains These fossils were not studied in detail, but they indicate that good Paleozoic sections are present in the Ketza River area.

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MANUSCRIPT RECEIVED DECEMBER 3, 1956

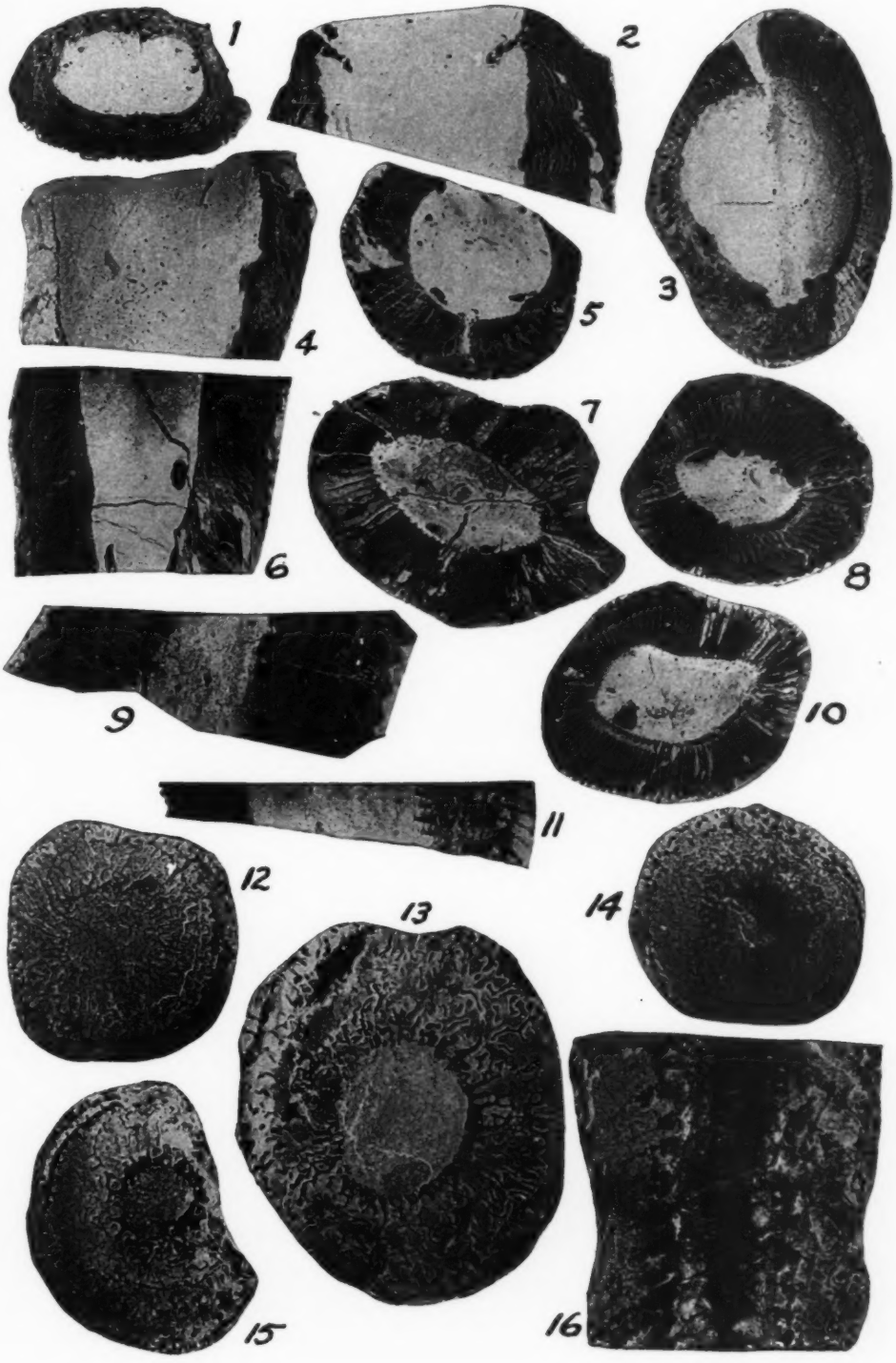
EXPLANATION OF PLATE 113

FIG. *1–6—Loculicyathus ellipticus*, n. sp. *1*, holotype, No. 35-Y-1, G.S.C. nol 13347, transverse section showing parieties and dissepiments in the intervallum, ×1½. *2*, holotype, No. 35-Y-1, G.S.C. no. 13347, longitudinal thin section showing vesicular tissue, ×2. *3*, paratype, No. 35-Y-2, G.S.C. no. 13348, transverse thin section showing intervallum partly filled with dissepiments and partly clear, ×1½. *4*, paratype, No. 35-Y-2, G.S.C. no. 13348, longitudinal thin section showing intervallum region, ×1½. *5*, paratype, No. 35-Y-3, G.S.C. no. 13349, transverse thin section showing radial parieties and dissepiments, ×2. *6*, paratype, No. 35-Y-3, G.S.C. no. 13349, longitudinal thin section showing porous parieties, 2.

7–11—Metacoscinus poolensis, n. sp. *7*, holotype, No. 40-Y-5, G.S.C. no. 13350, transverse thin section showing parieties and dissepiments in the intervallum, ×1½. *8*, paratype, No. 40-Y-3, G.S.C. no. 13351, transverse thin section showing parieties, dissepiments and inner wall, ×1½. *9*, paratype, No. 40-Y-3, G.S.C. no. 13351, longitudinal thin section showing tabulae and dissepiments, ×3. *10*, paratype, No. 40-Y-1, G.S.C. no. 13352, transverse thin section showing thin parieties and porous tabulae, ×1. *11*, paratype, No. 40-Y-1, G.S.C. no. 13352, longitudinal thin section showing tabulae, ×1½.

12—Metacoscinus sp. No. AP-6, U.B.C., transverse thin section, ×2.

13–16—Claruscyathus ketzaensis, n. sp. *13*, holotype, No. AP-2, U.B.C., transverse thin section showing irregular taeniae, ×3. *14*, paratype, No. AP-1, U.B.C., transverse thin section showing thick inner wall and irregular mass in the intervallum, ×2. *15*, paratype, No. AP-3, U.B.C., transverse thin section showing *Ethmophyllum*-like inner wall, ×3. *16*, paratype, No. AP-1, U.B.C., longitudinal thin section showing steeply dipping tabulae, ×3.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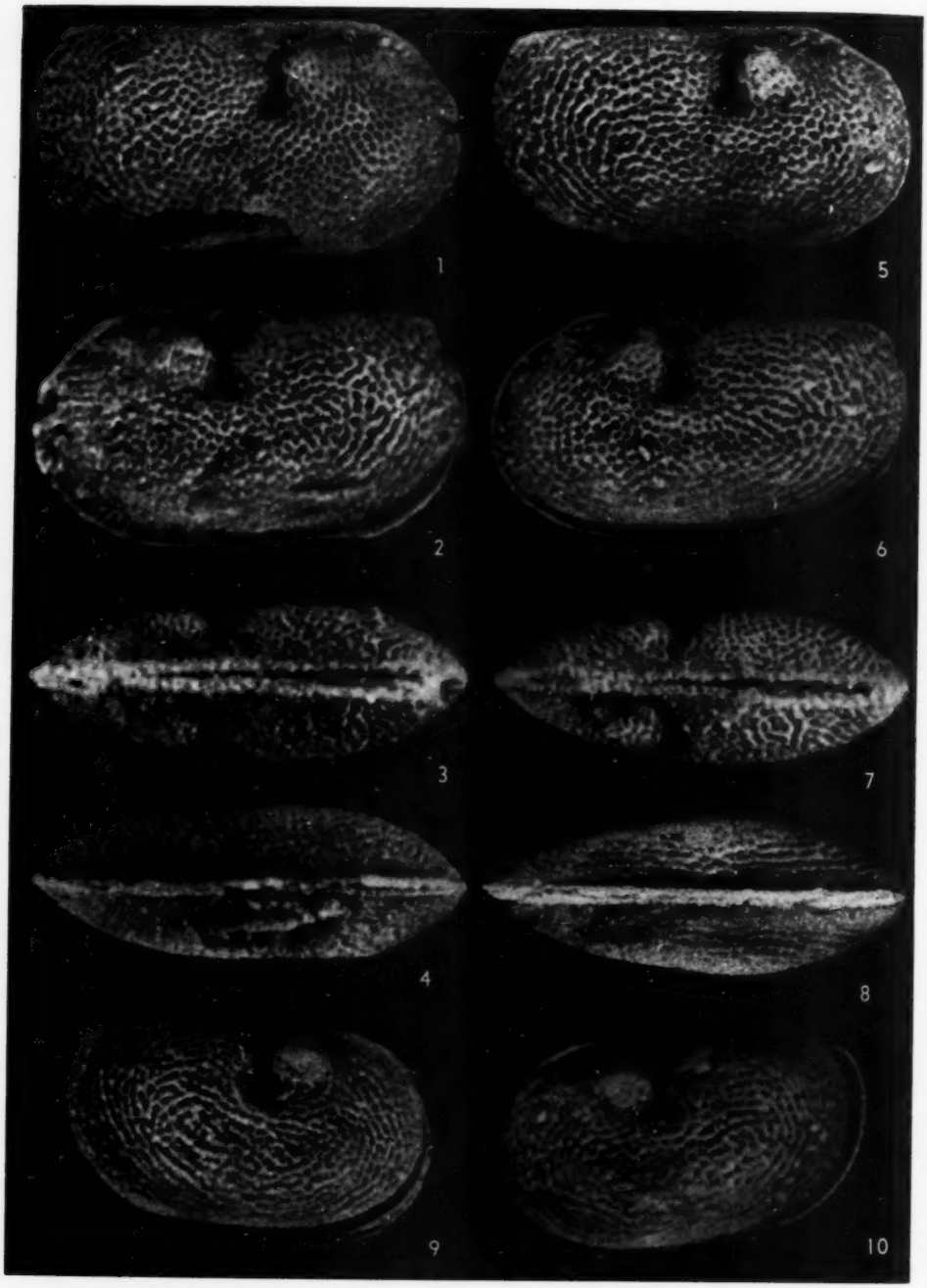
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JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 931–933, PL. 114, 1 TEXT-FIG., SEPTEMBER 1957

A NEW SPECIES OF THE OSTRACOD GENUS *KNOXIELLA* FROM THE MIDDLE DEVONIAN LUDLOWVILLE FORMATION OF WESTERN NEW YORK[1]

MURRAY J. COPELAND[2]

ABSTRACT—The presence of the genus *Knoxiella* is reported for the first time from North America, and *K. reticulata*, n. sp., is described from Middle Devonian strata of New York state.

INTRODUCTION

A NEW species of the genus *Knoxiella* Egerov 1950 is described in this paper. Specimens were obtained from the upper part of the Wanakah member of the Middle Devonian Ludlowville formation two miles southeast of East Bethany, Genesee County, New York. This is the first species of this genus to be reported from North America.

The author acknowledges his indebtedness to Mr. Raymond R. Hibbard of Buffalo, New York, for supplying the washed samples of shale from which the specimens were obtained. Dr. R. V. Kesling and Dr. L. B. Kellum of the University of Michigan offered helpful criticism of the manuscript.

All specimens are catalogued and deposited in the Museum of Paleontology of the University of Michigan.

SYSTEMATIC DESCRIPTION

Phylum ARTHROPODA
Class CRUSTACEA
Order OSTRACODA
Superfamily BEYRICHIACEA
Family KLOEDENELLIDAE Ulrich and Bassler 1923
(emend. Swartz 1933; emend. Egerov 1950)
Subfamily KNOXINAE Egerov 1950, p. 72

Genus KNOXIELLA Egerov 1950, p. 90

Genotype.—By original designation, *Knoxiella semilukiana* Egerov 1950, p. 90,93–94, pl. 15, fig. 25–34.

Description.—The following description is given, in translation, from Egerov 1950, p. 90–91:

Genus KNOXIELLA n. gen.

1. Holotype *Knoxiella semilukiana* n. sp.

2. Diagnosis. Knoxinae without any traces of the posterior dorsal spine or ventral rib in the adult forms.[3] The valve consists of three parts; furrows [sulci] may be almost completely obsolete.

3. Description. Carapace truncate to oval with a straight hinge. The right valve is the larger and overlaps the left valve on all sides. The maximum overlap occurs on the ventral margin; the valves meeting almost without overlap on the hinge line. A furrow is present along the edge of the right valve. The tapering edge of the left valve becomes inserted in this furrow when the valves are closed. Sometimes the furrow cannot be distinguished on the hinge rim. Small "ears" may be present in most specimens on the posterior and anterior ends of the hinge line of the right valve; when the valves are closed they overlap the edges of the left valve. In some specimens they are poorly developed or cannot be distinguished. The ventral margin of the right valve is more convex than that of the left valve and the right valve is relatively higher than the left one. The ventral margin of the right valve is more or less deflected toward the left valve and may be accompanied by a bolster-like thickening [marginal ridge]. The curvature of the outline of the valves is usually

[1] Published with permission of the Deputy Minister Department of Mines and Technical Surveys, Ottawa, Ontario.

[2] Geologist, Geological Survey of Canada.

[3] Immature molts are known only for *Knoxiella cerata:* in this species they have a well-developed posterior dorsal spine and ventral rib.

EXPLANATION OF PLATE 114

All figs. ×70

FIG. *1–10*—*Knoxiella reticulata*, n. sp. *1–4*, right lateral, left lateral, dorsal, and ventral views of a complete carapace; Paratype No. 33735. *5–8*, right lateral, left lateral, dorsal, and ventral views of a complete carapace; Holotype No. 33734. *9–10*, right lateral, and left lateral views of a crushed carapace; Paratype No. 33736.

poorly developed; sometimes, however, it is distinct. In this case the anterior dorsal angle is greater than the posterior dorsal angle and the posterior ventral angle is greater than the anterior angle. The valve is divided by two furrows [sulci] into three lobes, which have the appearance of strongly smoothed up mounds. The anterior furrow is shorter than the posterior one; sometimes it is very feebly developed. In *Knoxiella minima* both furrows are reduced; barely noticeable depressions can be observed with difficulty in some specimens instead of furrows. The posterior dorsal spine and the ventral rib are completely absent in adult forms. The immature molts of *K. cerata* have a well developed posterior dorsal spine in the early stages of development and a distinct ventral rib.

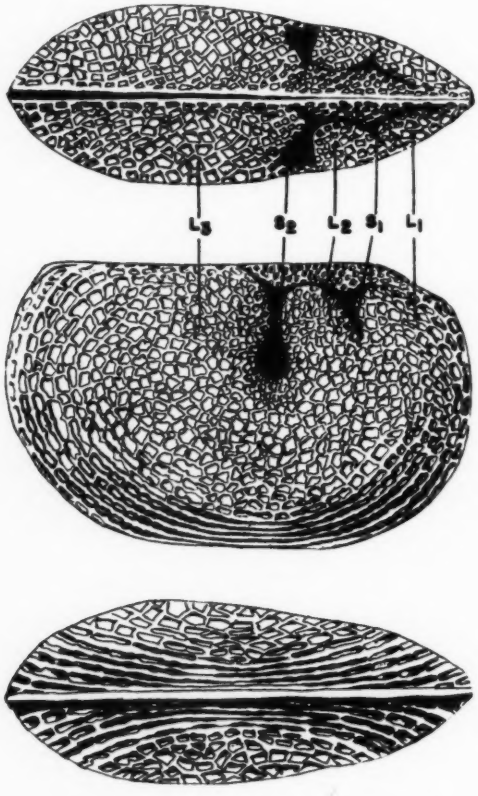
The surface of the valves is finely reticulate or smooth.

Sexual dimorphism. Males are not known for all of the species. Females are characterized by a strongly swollen posterior lobe, where the maximum thickness of the valve occurs. In males the posterior lobe is either less swollen (*K. wibitiensis, K. posneri*) or flattened (*K. donensis, K. konensis*) Also in males the maximum thickness of shells occurs in the posterior half of the valve; in comparison with female specimens, however, this occurs much nearer the middle of the valve.

4. Comparisons. Differences in the character of sexual dimorphism in species grouped within the genus *Knoxiella* show that it may be possible to subdivide this group more finely in the future. It appears that males and females of *K. donensis* and *K. konensis* differ from each other in the same fashion as males and females of the genus *Knoxites*. At the same time males and females of *K. posneri, K. wibitiensis* and, apparently, those of the species *K. variabilis* closely allied to the latter form, differ from each other in a somewhat different fashion. At the present time there are not enough data for subdivision of this genus.

5. Distribution. Devonian, Frasnian Stage—Carboniferous.

The foregoing appears to agree in many respects with the description of *Jonesina* Ulrich and Bassler 1908. *Knoxiella* apparently differs from *Jonesina* in having the posterior part of the hinge sunken in a V-shaped channel. Specimens of *Knoxiella*



TEXT-FIG. *1*—Reconstruction of a complete carapace of *Knoxiella reticulata*, n. sp., showing the dorsal, right lateral, and ventral views. Approximately ×70.

and *Sansabella* Roundy have a superficial similarity as seen in lateral view, but they have distinctly different hinge structures.

KNOXIELLA RETICULATA, n. sp.
Pl. 114, fig. 1–10

Description.—Carapace small, oval to subquadrate in lateral view, elongate oval in dorsal view. Right valve larger than left; overlap distinctly R/L around the free edge. Hinge line straight, about four-fifths as long as the carapace, hinge sunken in shallow V-shaped channel extending from above L2 to the posteroventral corners of the valves. Anterior and posterior borders broadly rounded; anterodorsal border truncated, posterodorsal corner forming a distinct angle; ventral border straight. Contact margins of both valves with a thickened marginal ridge, that of the right valve larger than the left.

L1 a low, indistinct lobe near the truncated anterior corner, sloping gently parallel to the anterodorsal part of the free border, ventrally confluent with the main part of the valve, dorsally merging with the gently convex anterodorsal shoulder below the dorsal border. L2 a rounded node in the dorsal half of the valve, its diameter about one-quarter the height of the valve, its dorsal edge separated from the hinge line by the anterodorsal shoulder and the dorsal confluence of S1 and S2, anteriorly and posteriorly bounded by sulci, ventrally confluent with the main part of the carapace. L3 the broadly rounded posterior lobe extending slightly above the sunken hinge line, bounded anteriorly by S2 and ventrally confluent with the main part of the carapace. In dorsal view L1 and L2 project posteriorly, L3 projects anteriorly.

S1 short, indistinct, less than one-fifth the height of the valve, dorsally confluent with S2 around the upper edge of L2. S2 situated about four-ninths of the total length of the valve from the anterior margin, extending ventrally from slightly below the hinge line two-fifths the distance to the ventral margin, deepest in its ventral half where it forms a pronounced pit.

Anterior cardinal angle truncated, about 140 degrees, posterior cardinal angle about 115 degrees.

Surface ornamented with shallow, closely spaced, polygonal reticulae forming a distinct meshlike pattern. Reticulae small and irregular on L2, along the anterodorsal border, and around S1 and S2, but much larger on the central part of the carapace; those near the free border elongate, aligned in 5 or 6 distinct rows separated by equally distinct ridges extending parallel with the free border, converging slightly near the middle of the ventral margin.

Dimensions of the figured specimens (in mm.) are as follows:

	Length	Height	Width
Holotype No. 33734	.83	.45	.32
Paratype No. 33735	.86	.47	.31
Paratype No. 33736	.73	.39	—

Remarks.—The sex of the specimens examined cannot be determined with certainty. The lack of posterior obesity may indicate them to be males. It is assumed that they are adult individuals.

Knoxiella reticulata, n. sp., closely resembles *K. accepta* Polenova (1952, pl. 6, fig. 6*a–b*), but differs from it in several structures. *K. reticulata* has a poorly developed L1, a straight dorsal border, and distinct reticulae arranged in rows near the free margin, but *K. accepta* has a more pronounced L1, a somewhat sinuous dorsal border, and shallower, less distinct reticulae, not in rows on any part of the valves.

Types.—Holotype, a complete carapace, No. 33734; paratypes, a complete carapace and a crushed carapace, Nos. 33735 and 33736.

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ONTOGENY OF *ELLIPTOCEPHALA*, *PARADOXIDES*, *SAO*, *BLAINIA* AND *TRIARTHRUS* (TRILOBITA)

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ABSTRACT—The original material of *Elliptocephala asaphoides* described by Ford in 1877 and 1881, is figured and redescribed. A protaspis is not represented. The smallest specimens are meraspid cephala bearing both genal and intergenal spines, and there is no later subdivision of the intergenal spine. The supposed protaspis of *Paradoxides rugulosus* of Raymond, 1914, is a meraspid cranidium. A meraspis degree 9 of this same species is illustrated again. Protaspides of *Sao hirsuta* from 0.7 to 1.0 mm. in length have opisthoparian sutures, probably a rostrum, and a large hypostome. Palpebral lobe, eye ridge and an anterior pit are visible, as also is a sutural ridge running distally from the anterior extremity of the glabella. Lalicker's material of *Blainia gregaria?* is poorly preserved, but protaspides 0.4 to 0.6 mm. in length do not have eye ridge, palpebral lobe, and dorsal facial sutures in the positions he portrayed them. Large protaspides and small meraspid cranidia have the palpebral lobe on anterolateral margin, eye ridge reaching axial furrow behind anterior pit, and the anterior extremity of glabella extended along margin of the shield, in front of anterior pit, by a low ridge. Probably the facial suture is opisthoparian in early meraspides, but its course cannot be traced in the protaspides. Descriptions of meraspides degree 1–15 and of the holaspis of *Triarthrus eatoni* include new illustrations of Walcott's original material from the Holland Patent shale. It is suggested that *Porterfieldia* Cooper, 1953, is a synonym of *Triarthrus*. The protaspis believed by Beecher to be that of *T. eatoni* lacks free cheeks, has two ill-defined pairs of lateral glabellar lobes and a third ring furrow, and a broad border on the protopygidium. It is most probably not the protaspis of *T. eatoni*, and may be that of a bathyurid or proetid. A size series of the protaspis believed by Beecher to be that of *"Proetus" beecheri* is described, and is thought to be a phacopoid protaspis.

INTRODUCTION

IN THE course of the preparation of an essay on the ontogeny of trilobites, I studied material of *Paradoxides rugulosus*, *Sao hirsuta*, *Blainia gregaria?*, and *Triarthrus eatoni* in the Museum of Comparative Zoology. I found that the supposed protaspis of *P. rugulosus* was a meraspid cranidium, that small protaspides of *S. hirsuta* have an opisthoparian, not a proparian, suture, and arrived at an interpretation of protaspides of *B. gregaria?* quite different from Lalicker's. New illustrations and descriptions of meraspides of *T. eatoni* are given. The protaspis of *"T. eatoni"* was obtained by Beecher from a different horizon and locality to that which yielded meraspides to Walcott. I borrowed this protaspis for study, together with a second protaspis from the same locality. Illustrations and descriptions of each are given, but I do not think either is *T. eatoni*, and do not identify either more closely than to family or superfamily. Dr. C. J. Stubblefield reminded me that Ford had published an illustration of a supposed protaspis of *Elliptocephala asaphoides*. Study of Ford's original material showed this illustration to be in error, for a protaspis is not present. Both genal and intergenal spines are present in tiny meraspid cephala. This discovery eliminates the necessity for the peculiar mode of growth of the posterior cephalic border advocated by Ford.

It is hoped that these descriptions will lay the ghosts of various pioneer illustrations that continue to haunt the literature, dragging in their train the theories derived from them.

I am indebted to Mr. Clinton F. Kilfoyle, New York State Museum, Albany (NYSM) for the loan of Ford's material of *Elliptocephala asaphoides;* to Dr. G. Arthur Cooper, United States National Museum, Washington, D. C., for the loan of material of this species studied by Dr. C. Lochman; and to Professor Karl M. Waagé, Peabody Museum of Natural History, Yale University (YPM), for the loan of Beecher's specimens of protaspides. Initials in brackets, in-

cluding MCZ for Museum of Comparative Zoology, Harvard University, are used subsequently in referring to particular specimens. Mrs. Robert E. Kay and Mrs. L. Sparks Swartz prepared the enlargements from my negatives.

SYSTEMATIC PALEONTOLOGY

ELLIPTOCEPHALA ASAPHOIDES Emmons, 1844

Pl. 115, fig. 1–6

Description.—Developmental stages of this species were first described by Ford (1877, 1881) and later by Walcott (1910, p. 236–246, Pl. 25, fig. 1–18), from Lower Cambrian rocks at Troy, New York. Walcott's illustrations included figures drawn for him by Ford and illustrations of a "paraprotaspis" and a small cephalon redrawn from specimens earlier described (Walcott, 1886, Pl. 17, fig. 5,6). Ford's and Walcott's figures have been reproduced by authors at frequent intervals (e.g. Warburg, 1925, fig. 4; Stubblefield, 1936, fig. 8; Størmer, 1942, fig. 3,5; Hupé, 1954, fig. 49), theoretical deductions made from them, and at least one new term proposed for features depicted in them. A re-examination of Ford's original material shows, however, that these drawings are far from accurate, particularly those of the tiniest specimens. Some of these specimens may be re-described as follows: NYSM 4595 (Pl. 115, fig. 1).—Cephalon subcircular in outline, median region strongly convex and sloping steeply down to the lateral and anterior borders. Glabella partially outlined by straight axial furrows extending as far forward as the back of the eye ridge. Within this region is the short (sag.), convex occipital ring isolated by an occipital furrow, deepest distally, and three longer rings, the anterior margin of each delimited by a shallow pit in the axial furrow. In front of the anterior pair of these pits is the subcircular frontal glabellar lobe, wider than the remainder of the gabella, faintly defined laterally by extremely shallow continuations of the axial furrows, anteriorly outlined by its convexity from the concave border region. Eye ridge joined to posterolateral part of frontal glabellar lobe, curving backward and outward and merging into the wider and more elevated crescentic eye lobe. Latter extends from opposite base of frontal glabellar lobe to first lateral glabellar pit in front of occipital furrow. Posteriorly eye lobe continuous with prominent narrow ridge (post-ocular ridge or posterior eye line) which runs across concave border region and along outer edge of intergenal spine. Cheek between glabella and eye lobe elevated, posterolaterally sloping down to concave border region, and posterolateral corner continued by ridge (as prominent as post-ocular) which cuts diagonally across posterior border and runs along inner edge of intergenal spine. Latter with deep median channel between lateral ridges. Outside eye lobe and in front of glabella is broad, concave border region, which at edge of cheeks and preglabellar field passes into narrow, convex border. Opposite occipital furrow, and outside intergenal spine, a tiny genal spine projects outward from this border (see left side of Pl. 115, fig. 1). Between the bases of the intergenal spines is the transverse edge of the posterior borders, and the backward-projecting curve of the posterior margin of the occipital ring. There is no trace of the "rudimentary thorax and pygidium combined" (Ford, 1877, p. 268) depicted and described by Ford (1877, Pl. 4, fig. 2), and it is notable that this portion is not shown in Ford's later drawings (Walcott, 1910, Pl. 25, fig. 1–8). I have no doubt but that the line bounding the specimen between the intergenal spines ran along a joint in the exoskeleton, i.e. that this was a meraspid cephalon.

NYSM 4594 (Pl. 115, fig. 3).—Cephalon, 1.55 mm. in length, quite similar to 4595, but occipital ring now wider than the three rings in front of it, which are separated from each other by shallow ring furrows ending distally in pits. Intergenal spine, and ridges running into it, much as in smaller specimen, genal spine larger and relatively farther forward—situated opposite ring in front of occipital. On cheek inside eye lobe an extremely faint furrow curves out from opposite second ring furrow in front of occipital and back toward tip of eye lobe.

NYSM 4604 (Pl. 115, fig. 2).—Probably a meraspis, cephalon of length 2.9 mm., 9 thoracic segments may be counted, pygidium small and extremely poorly preserved. Chief change in cephalon is presence of much broader cheek and preglabellar area outside

eye lobes and in front of glabella. Frontal lobe of latter now clearly bounded by change in slope. Outer part of cheek and preglabellar field convex proximally, distally becoming concave inside the narrow, convex border. Eye lobe distinctly outlined, connected to frontal glabellar lobe by extremely short eye ridge. Genal and intergenal spines of equal size, narrow posterior border running outward and forward between their bases. Intergenal spine connected by low ridges to eye lobe and inner corner of cheek. Thoracic segments with pleural furrows, third segment the most prominent, the broad pleurae extended back into long spines.

NYSM 4605 (Pl. 115, fig. 4).—Probably an holaspis, cephalon 4.1 mm. in length, 13 thoracic segments may be counted, pygidium not preserved. Glabella of four rings of equal width and subcircular frontal lobe, two lateral furrows in front of occipital deeper and extending short distance inward. Posterior border now running in almost straight transverse line from axial furrow to base genal spine. Latter much longer than intergenal, which is blunt point connected by single narrow ridge to tip of eye lobe and swollen part of cheek inside it. The cephalon is slightly larger than the original of Ford's 1877, Plate 4, figure 3, but shows similar features. Thorax with pleurae of third segment extended into long spine.

NYSM 4597 (Pl. 115, fig. 6).—Larger cephalon than that of 4605, preserved as counterpart moulds. Glabella narrowing forward from occipital ring to second ring in front, then widening to frontal lobe. Second ring furrow in front of occipital complete, third faint and incomplete. Notable is the swollen region of cheek between eye lobe and first glabellar ring in front of occipital. Tip of this region abuts against posterior tip of eye lobe, and both are connected by faint ridge to the much reduced intergenal spine. The post-ocular ridge of the holaspis may thus be a fused remnant of the two ridges seen in the earliest meraspides (compare Pl. 115, fig. 1, with Pl. 115, fig. 6). Cheek region outside eye lobes, and preglabellar field, crossed by anastomosing ridges. Two stronger ridges diverge laterally from the anterior tip of the eye lobe. One of these ridges may correspond to the preocular ridge (or anterior eye line) of authors (e.g. Størmer, 1942, Pl. 2, fig. 1,3; Hupé, 1954, fig. 46) but in this example it has no connection with supposed remnants of facial sutures.

NYSM 4598 (Pl. 115, fig. 5).—A holaspis lacking the posterior thoracic segment and pygidium. The pattern of radiating, anastomosing ridges on outer parts of cheeks and preglabellar field is well displayed. Swollen area of inner part of cheek no longer visible. Genal spine long, intergenal reduced and barely visible, but postocular ridge remains. Third thoracic segment with pleural spines reduced to same size as those of adjacent segments.

Discussion.—For the reasons given above, the smallest specimens known of *E. asaphoides* are believed to be meraspid cephala, and not protaspides. I have examined the material recently described by Lochman (1956, p. 1376–1377), and none of these specimens is a protaspis. The meraspid cephala are poorly preserved in many cases, but show the same features as Ford's, including the genal spines outside the intergenal. Størmer (1942, p. 60–61, text-fig. 4,5e, Pl. 2, fig. 6,7) thought that the small cephalon of *Holmia kjerulfi?* that he described was probably a meraspis. It is similar in size and appearance to NYSM 4594 (Pl. 115, fig. 3), displays both genal and intergenal spines, and is distinguished particularly by showing better-defined pairs of furrows on the inner areas of the cheeks. I feel confident that both these specimens are of meraspid cephala. Dr. A. R. Palmer kindly examined the originals of Walcott's 1910, Plate 25, figures 9 and 10, the former of which is smaller than any of Ford's specimens. He believes (personal communication) that they are meraspid cephala, but reports that they are poorly preserved and that whether or not genal spines are present cannot be decided. The drawings based on them involve a good deal of reconstruction. It does not seem useful to continue to employ Warburg's (1925, p. 21) term "larval ridge" for the supposed combination in a single ridge of frontal glabellar lobe, eye ridge, eye lobe and post-ocular ridge. This term was based on the schematic way in which Walcott (1910, Pl. 25, fig. 9) represented these features in tiny cephala of *E. asaphoides*, and

not as they actually appear.

As a result of the discovery of genal spines outside the intergenal spines of the smallest cephala, we need no longer follow Ford (1877) in believing that the intergenal spine was composite in early stages, and that the two parts separated later to form the genal and intergenal spines. Raw (1927, p. 291–294; 1937, p. 583) offered a different explanation of the relationships between genal and intergenal spines in this species. I see no reason from the available material, however, to assume that the intergenal spine is the fused "metacranidial" and "parial" spines of Raw, or that the genal is his "procranidial" spine.

PARADOXIDES RUGULOSUS Corda, 1847
Pl. 115, fig. 8,9

Raymond (1914, p. 232, Plate, fig. 8) described what he called a protaspis of *Paradoxides* sp. ind., from the Middle Cambrian at Teiřovic, Bohemia, and his figure has been copied by recent authors (e.g. Størmer, 1942, fig. 7f; Hupé, 1954, fig. 19,2). Růžička (1943, p. 23–25) has shown that this "larva" belongs to the *P. rugulosus* species-group. Re-examination of the specimen (Pl. 115, fig. 8) shows, however, that it is not a protaspis but a meraspid cranidium, as Raw (1925, p. 291) apparently thought. The occipital ring is transversely ovate in outline, projecting behind the posterior border of the fixed cheek, which runs out transversely to the base of the fixigenal spine. Two glabellar rings in front of the occipital are demarcated by deep ring furrows. A third, slightly longer (sag.) ring is less clearly defined, and the frontal glabellar lobe wider than the lobes behind, subcircular in outline and divided by a median longitudinal furrow. The eye ridge runs out from the postero-lateral margin of the frontal glabellar lobe into the raised ridge of the palpebral lobe. The latter ends posteriorly opposite the first glabellar ring furrow in front of the occipital, and does not extend to the base of the fixigenal spine as Raymond claimed. The lateral margins of the specimen are defined by the sutures, the anterior branch curving gently forward and slightly inward across the anterior border. The posterior branch is straight, directed backward and slightly inward. Inside the eye lobe the fixed cheek is convex, sloping steeply to the palpebral furrow and to the depressed outer part adjacent to the posterior branch of the suture. I consider the posterior margin of the specimen to be along the joint behind the cephalon, and see no sign of a protopygidium. This cranidium is 0.89 mm. in length, and similar in size and form to the original of Růžička's Plate 2, figure 4, which is likewise a cranidium (as also is the original of his figure 5). The original of Růžička's Plate 2, figure 2, is a protaspis showing both librigenal and fixigenal spines, and in this and other respects like the protaspis of *Paradoxides pinus* Holm? (Westergaard, 1936, Pl. 4, fig. 3,4a,4b). Raymond (1914, p. 229, Plate, fig. 9) also described a meraspis of *P. rugulosus*, degree 9, total length 3.5 mm., of cephalon 1.7 mm. (Pl. 115, fig. 9). It is larger than the degree 7 specimen described by Růžička (1943, Pl. 2, fig. 8), otherwise quite similar except that the pleural spine of only the second thoracic segment is long, the first now being short. A similar relative change in length of first and second pleural spines of the thorax occurs in the development of *P. pinus?* (Westergaard, 1936, Pl. 4, fig. 22; Pl. 5, fig. 7).

SAO HIRSUTA Barrande, 1846
Pl. 115, fig. 21,22; Pl. 116, fig. 14–21.

Barrande's studies (1852) have made classical the developmental history of this Bohemian Middle Cambrian species. Růžička (1943) gave some additional details, and the specimens described here add further detail and suggest some modifications of Růžička's views. The smallest protaspis in the Museum of Comparative Zoology collection is 0.6 mm. in length (Pl. 116, fig. 14), subcircular in outline, the pleural regions strongly convex so that laterally they slope vertically. Axis well-defined, most prominent ring the occipital, in front of which is a second ring of similar length and width, then two ill-defined rings of similar size, and an anterior ring which widens rapidly forward. Near the anterior extremity of the outward-curving axial furrow, just inside the margin of the shield, is the shallow anterior pit. Axis behind occipital ring convex, not subdivided, rounded tip just inside transverse posterior

margin of shield. Palpebral lobe on antero-lateral margin of shield, opposite fourth glabellar ring, and connected by low (sutural ?) ridge to distal extremity of frontal glabellar ring. Subdivision of pleural regions suggested by change in slope which runs diagonally back from a point opposite base of occipital ring. Short spine present at posterolateral corner of protaspis, spines on posterior margin apparently absent.

A slightly larger specimen, 0.7 mm. in length (Pl. 116, fig. 15), displays similar characters, but is of interest in having the displaced free cheek preserved beside it. All the material of *S. hirsuta* that I have seen is preserved as internal moulds of the dorsal exoskeleton (and external of the ventral) in siltstone, and this cheek is represented only by the external mould of the doublure, a narrow strip 0.04 mm. wide. The posterior part of this strip, lying outside of, and just behind the palpebral lobe (Pl. 116, fig. 15) widens and then tapers to a blunt point. This is the ventral side of the genal spine. The anterior end of the strip is cut off abruptly along a transverse line, and measurements show that, if this strip were placed in position, this line would lie under the outer part of the frontal glabellar lobe. This line may be that of the connective suture, and suggests that a rostrum was present at this stage. The dorsal facial suture must have run close to the outer edge of the cheek, which sloped vertically, and hence the dorsal part of the free cheek was extremely narrow. The fact that the genal spine was borne by the free cheek shows that the posterior branch of the suture must have curved inward across the base of the genal spine on the dorsal side, i.e. that the suture was opisthoparian at this stage. The anterior pit is visible, and particularly on the right side may be seen the palpebral lobe and eye ridge curving in to reach the axial furrow just behind the anterior pit.

A larger protaspis (Pl. 116, fig. 18), 0.8 mm. in length, lacks free cheeks but shows a similar subdivision of the glabella. Palpebral lobe, eye ridge, anterior pit, and ridge

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EXPLANATION OF PLATE 115

FIG. *1–6—Elliptocephala asaphoides* Emmons, Lower Cambrian, Troy, N. Y. *1*, cephalon, dorsal stereograph, NYSM 4595, original of Ford, 1877, Pl. 4, fig. 2, ×30. *2*, probably a meraspis, dorsal stereograph, NYSM 4604, original of Ford, 1881, fig. 1, ×6. *3*, cephalon, dorsal stereograph, NYSM, 4594, original of Ford, 1877, Pl. 4, fig. 1, ×20. *4*, probably an holaspis, dorsal view, NYSM, 4605, original of Ford, 1881, fig. 2, ×4. *5*, incomplete holaspis, dorsal view, NYSM 4598, original of Ford, 1877, Pl. 4, fig. 5; 1881, fig. 3, ×2. *6*, cephalon, dorsal view, NYSM 4597, original of Ford, 1877, Pl. 4, fig. 4, and ? of Walcott, 1910, Pl. 25, fig. 6, ×6.

7,12–14—Blainia gregaria Walcott?, Middle Cambrian, Conasauga formation, Moshats cross roads east of Center, Cherokee Co., Ala. *7*, meraspid cranidium, dorsal view, MCZ 5447e, original of Lalicker, 1935, Pl. 47, fig. 5, ×30. *12*, protaspis, dorsal view, MCZ 5447a, original of Lalicker, 1935, Pl. 47, fig. 1, ×50. *13*, protaspis, dorsal view, MCZ 5447b, original of Lalicker, 1935, Pl. 47, fig. 2, ×50. *14*, protaspis, dorsal view, MCZ 5447f, original of Lalicker, 1935, Pl. 47, fig. 6, ×30.

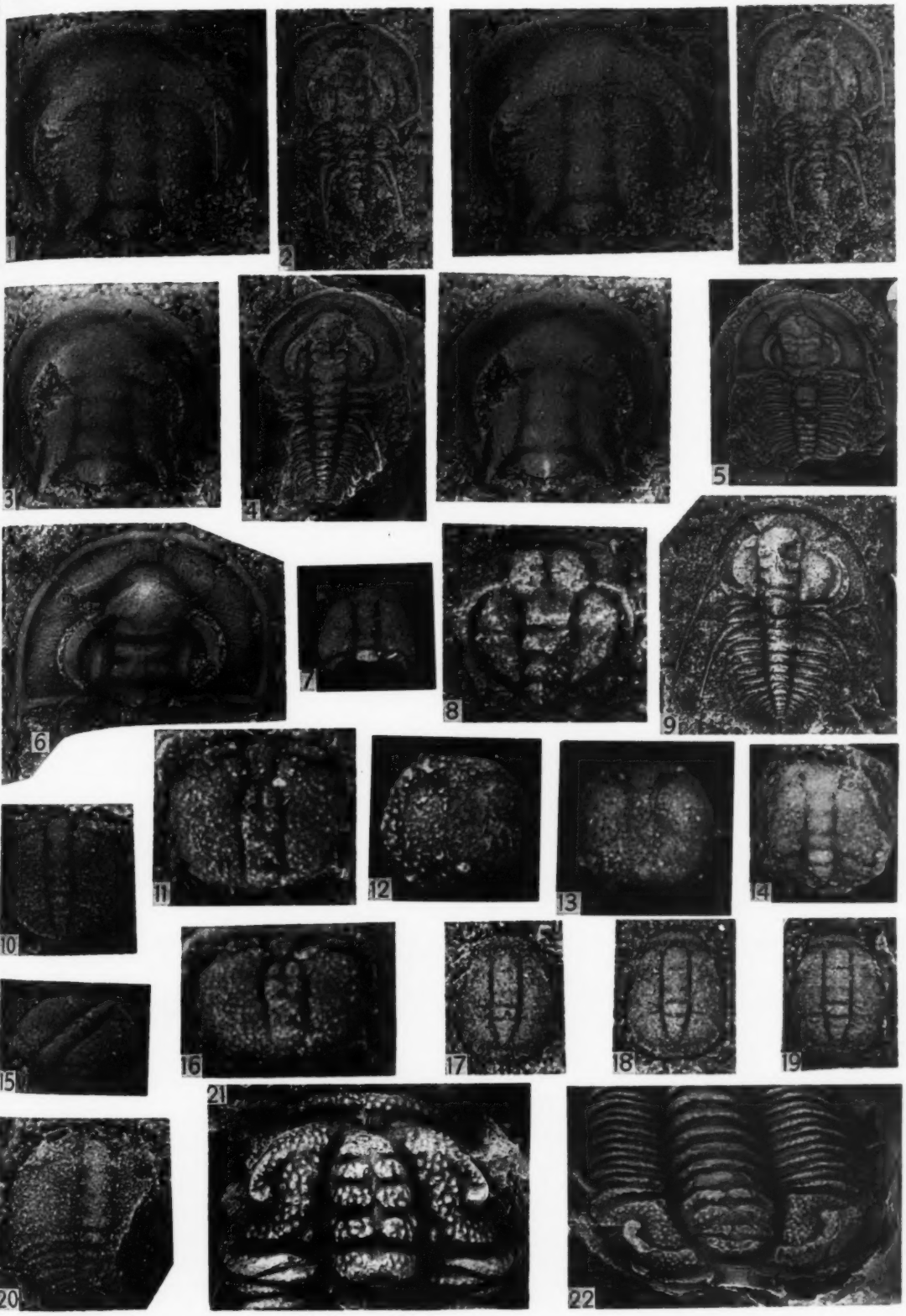
8,9—Paradoxides rugulosus Corda, Middle Cambrian, Bohemia. *8*, meraspid cranidium, dorsal view, from Teiřovic, Schary collection, MCZ 33, original of Raymond, 1914, fig. 8, ×30. *9*, meraspis degree 9, dorsal view, from Slap, Schary collection, MCZ 423, original of Raymond, 1914, fig. 9, ×10.

10, 11, 15,16,20—Protaspis B, Frankfort shale, Six Mile creek, near Rome, N. Y. *10,15*, larger stage, dorsal and antero-lateral views, YPM 6609, original of Beecher, 1895, Pl. 9, fig. 5, ×30. *11,16*, smallest stage, dorsal and postero-dorsal views, YPM 6608, ×50. *20*, largest stage, dorsal view, YPM 6671, original of Beecher, 1895, Pl. 9, fig. 6, ×30.

17–19—Protaspis A, Frankfort shale, Six Mile creek, near Rome, N. Y. *17*, dorsal view, YPM 6597B, one of two originals of Beecher, 1895, Pl. 8, fig. 13, ×30. *18*, dorsal view, MCZ 2976, ×30. *19*, dorsal view, YPM 6664B, one of two originals of Beecher, 1895, Pl. 8, fig. 12, ×30.

21,22—Sao hirsuita Barrande, Middle Cambrian, Skrey, Bohemia. *21*, internal mould, showing cranidium and anterior thoracic segments, dorsal view, Schary collection, MCZ 3089, ×4. *22*, external mould of doublure combined with internal mould of remainder of exoskeleton, antero-dorsal view showing rostrum, Barrande collection, MCZ 3094, ×4.

Right hand figure of pair forming a stereograph not numbered.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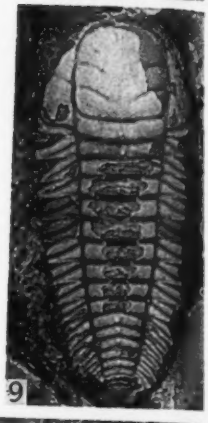
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extending from extremity of frontal glabellar ring along antero-lateral margin are most clearly visible on left side. Pleural regions are subdivided into cephalic and protopygidial parts. Axis of protopygidium divided into three rings.

The largest protaspides, 0.98 mm. in length, have the protopygidium divided into 4 rings, and shallow pleural furrows and interpleural grooves delimit the first two pleurae. One specimen (Pl. 116, fig. 19) has the displaced hypostome lying beside the left pleural region of the protopygidium. The triangular middle body is extended into long, pointed anterior wings, and the postero-lateral borders are broad and bear at least one pair of spines. Růžička (1943, Pl. 4, fig. 11) figures a smaller protaspis in which the hypostome is only slightly displaced. The second specimen (Pl. 116, fig. 16,17) has part of the doublure of the left free cheek, continued into the longer genal spine, lying beside it. On the right side of the cheek of this specimen a sharp line runs just inside the margin and subparallel to it. This line I interpret as the inner edge of the doublure, preserved as an external mould with the internal mould of the rest of the dorsal exoskeleton. Neither of these specimens has the palpebral lobes clearly preserved, but these are seen in examples of a similar size of degree 0. One of these (Pl. 116, fig. 20) has the doublure of the cephalon preserved as a smooth band around the margin and continued into the genal spine, and the right palpebral lobe and eye ridge lie at the inner edge of this band. The dorsal surface of the free cheek must have been of about the same width as this band, and carried the visual surface of the eye lobe. Both palpebral lobes are well seen in the second degree 0 specimen (Pl. 116, fig. 21), but free cheeks are missing, the doublure of the left preserved a short distance away. Three pairs of pleurae are defined in the protopygidium.

The protaspides described above show that, from a length of 0.6 mm. upwards, the glabella is divided into 5 rings, and the palpebral lobe clearly visible because of its convexity and the furrow which bounds it on the inner and posterior sides. The anterior side, however, is prolonged into the narrower and lower eye ridge, which meets the axial furrow immediately behind the anterior pit. In addition, the anterolateral extremity of the glabella is extended outward along the margin of the shield by a ridge. This ridge runs in front of the eye ridge, and must lie on the line of the anterior branch of the facial suture. It may therefore be a sutural ridge (Whittington and Evitt, 1954, p. 17–19). Rasetti (1954, text-fig. 4a,b) has clearly protrayed palpebral lobe, eye ridge and sutural ridge in the protaspis of *Welleraspis swartzi*, and these features may also be discerned in the large protaspis of *Blainia gregaria?* (Pl.

EXPLANATION OF PLATE 116

FIG. *1–13—Triarthrus eatoni* (Hall), Holland Patent shale, Trenton, Oneida Co., N. Y., C. D. Walcott collection. Dorsal views, except fig. 12, oblique view. *1*, meraspis degree 1, MCZ 5445B, ? original of Walcott, 1879, Pl. 2, fig. 1a,15, ×30. *2*, meraspis degree 2, MCZ 5445C, ? original of Walcott, 1879, Pl. 2, fig. 2, ×30. *3, 4*, meraspides degree 3, MCZ 5446A, ×20. *5*, meraspis degree 4, MCZ 5446B, ×20. *6*, meraspis degree 5, MCZ 5445E, ? original of Walcott, 1879, Pl. 2, fig. 5, ×10. *7*, meraspis degree 7, MCZ 5446C, ×10. *8*, meraspis degree 9, MCZ 5445H, ? original of Walcott, 1879, Pl. 2, fig. 9, ×10. *9*, meraspis degree 14, MCZ 5445M, ? original of Walcott, 1879, Pl. 2, fig. 13, ×6. *10*, holaspis, MCZ 5445P, ×3. *11*, anterior part of cranidium, showing anterior pairs of lateral glabellar furrows and right palpebral lobe, MCZ 5445P, ×4. *12*, cranidium, MCZ 5446D, ×6. *13*, anterior thoracic segments, right free cheek, and external mould of anterior doublure and hypostome, MCZ 5446E, ×4.

14–21—Sao hirsuta Barrande, Middle Cambrian, Teiřovic (except fig. 21, Skrey), Bohemia, Schary collection, ×30. *14*, smallest protaspis, lacking free cheeks, dorsal view, MCZ 3057. *15*, protaspis with external mould of doublure of displaced left free cheek lying beside it, MCZ 3028. *16, 17*, protaspis with external mould of part of doublure of left free cheek lying beside it, dorsal and antero-dorsal views, MCZ 5324B. *18*, protaspis, lacking free cheeks, dorsal view, MCZ 2986. *19*, protaspis, lacking free cheeks, external mould of displaced hypostome lying to left of protopygidium, dorsal view, MCZ 5324C. *20*, meraspis degree 0, internal mould combined with external mould of cephalic doublure, dorsal view, MCZ 5324A. *21*, meraspis degree 0, external mould of doublure of left free cheek lying beside it, MCZ 3019A.

115, fig. 14). Warburg (1925, p. 28), relying on illustrations that did not distinguish between eye ridge and sutural ridge, applied the term "larval ridge" to the elevated part of the margin extending from palpebral lobe to frontal glabellar lobe. It has been pointed out above that the term was erected with reference to misleading illustrations of *Elliptocephala asaphoides*, and it should no longer be used.

In protaspides of 0.7 mm. length and larger, opisthoparian dorsal facial sutures were present, and probably also connective sutures. The hypostome was relatively large. Růžička did not observe the free cheeks in the protaspides of similar size that he studied (1943, p. 29, Pl. 4, fig. 9–13), but observed them in the degree 1 meraspis (1943, Pl. 4, fig. 15). He did, however, attribute some tiny protaspides, 0.5 to 0.55 mm. in length (1943, p. 28–29, Pl. 4, fig. 7,8; Pl. 5, fig. 5), to *S. hirsuta*. These protaspides have a different outline to the smallest figured here, the axis some distance from the posterior margin, there is a border furrow postero-laterally, and a tiny spine on the lateral margin at the mid-length. Because of these differences I do not feel sure that these protaspides are of *S. hirsuta*. They bear some resemblance to a larger, un-named protaspis described by Růžička (1943, p. 31, text-fig.) from the same strata, and might be an earlier stage of this species. The present studies show, then, that the smallest protaspides certainly to be referred to *S. hirsuta* have an opisthoparian suture. Thus the claim (Poulsen, 1927, p. 330) that early meraspid degrees of this species exhibit a proparian stage is incorrect. Nor can the view of Raw (1925, p. 258–259; cf. Størmer, 1942, p. 81) be accepted that the genal spine is at first a "metacranidial," later a "parial" spine—it is a librigenal spine from the earliest certainly known stage.

Barrande (1852, p. 130,382–403, Pl. 7) did not describe or figure the connective sutures and rostrum of holaspides of *S. hirsuta*. A cephalon which combines an external mould of the doublure with an internal mould of the remainder of the exoskeleton (Pl. 115, fig. 22) shows the rostrum slightly displaced. An internal mould of the cranidium is illustrated for comparison (Pl. 115, fig. 21).

Blainia gregaria Walcott ?
Pl. 115, fig. 7, 12–14.

Developmental stages supposedly of this Middle Cambrian species were described by Lalicker (1935). It was stated that in protaspides ranging in length from 0.35 to 0.62 mm. the palpebral lobe, eye ridge, and dorsal facial suture were present on the anterior part of the cheek, close beside the frontal glabellar lobe. What we know of other protaspides does not make these claims sound probable, and both Stubblefield (1936, p. 427, footnote) and Størmer (1942, p. 90–91), have suggested that they might be based on mis-interpretations. A re-examination of the specimens convinces me that Lalicker's views cannot be upheld. The material is "very poorly preserved" (Lalicker, 1935, p. 394), the margins of the specimens being incomplete and broken.

The originals of Lalicker's Plate 47, fig. 1a,1b and 2 (Pl. 115, fig. 12,13) are subcircular in outline, convex, each 0.41 mm. in length. The axis is faintly outlined by shallow furrows, the median part parallel-sided, widening rapidly as the anterior margin of the shield is approached, narrowing posteriorly to the convex tip which is close to the margin of the shield. In the axial furrow, beside the wide anterior part of the axis, is a shallow pit. This is the anterior pit, and a similarly situated pit is seen in tiny protaspides of *Sao* (Pl. 116, fig. 14, 18) and other genera. On the posterior margin of the shield is a pair of spines, close together and directed downward. No further details can be discerned with certainty. These specimens are early protaspides, and the palpebral lobe must have been situated on the antero-lateral margin of the shield, in a transverse line with the anterior pit. The margins, however, are poorly preserved, and there is no evidence of the position of the facial suture and nature of the free cheeks.

The originals of Lalicker's Plate 47, figures 3,4, are larger protaspides, poorly preserved and incomplete. The original of his figure 6 is the best-preserved large protaspis, 0.57 mm in length (Pl. 115,

fig. 14). The axis is clearly outlined, subdivided into the most convex ring, the occipital, three rings in front of this of about the same length and width, and a longer and wider anterior ring, the antero-lateral corner of which is continued a short distance along the margin of the shield by a ridge. In the axial furrow, opposite the mid-length of the anterior glabellar ring, is the shallow anterior pit. A low eye ridge runs out transversely across the cheek from the axial furrow immediately behind the anterior pit to the palpebral lobe which extends along the antero-lateral margin of the shield to a point about opposite the level of the second ring furrow in front of the occipital. The posterior border furrow is deep, faintly convex border behind it. Axis of protopygidium short, not subdivided, rounded tip. This protaspis is exceedingly like that of *Welleraspis swartzi* (Rasetti, 1954, Pl. 62, fig. 1–4, text-fig. 4a,b), and also lacks free cheeks, for the suture must have run along the antero-lateral margin of the specimen, and not along the axial furrow, furrow on posterior side of eye ridge, and palpebral furrow, as portrayed by Lalicker (1935, Pl. 47, fig. 6a). Whether this specimen was "proparian" or "opisthoparian" cannot be determined, but the small meraspid cranidium (Pl. 115, fig. 7; length 0.45 mm.) suggests that it may have been opisthoparian. This cranidium is like that of the large protaspis, and of about the same size.

The original of Lalicker's (1935) Plate 47, figure 7, is too poorly preserved for me to be sure of its nature and orientation. The originals of his figures 8,9 and 10 are cranidia, that of figure 8 similar to, but larger than, the original of his figure 5.

It may be concluded, then, that Lalicker's material shows a developmental series similar to that displayed by far better preserved specimens of *Welleraspis swartzi* (Rasetti, 1954). The smallest stages attributed to *Blainia gregaria?* (Pl. 115, fig. 12,13), though of a similar size to the smallest protaspides of *W. swartzi*, display what appears to be an earlier stage of development—the axis faint and lacking subdivisions, the protopygidium undefined. This stage is not unlike that seen in the smallest protaspides of *Pseudocybele nasuta* (Ross, 1951, Pl. 83, fig. 13–18), 0.45 to 0.47 mm. in length.

Triarthrus eatoni (Hall, 1838)
Pl. 116, fig. 1–13

Walcott (1879, p. 23–33, Pl. 2, fig. 1–14) described a size series of "*T. becki*" from the "Utica slate, Trenton, Oneida Co., N.Y." This large collection is in the Museum of Comparative Zoology, and has been re-examined. It seems clear from Ruedemann's work (1925, p. 33–36; 1926, p. 119–121) that the specimens are from the Holland Patent shale, the upper one-third of the Utica formation, and should be called *T. eatoni*. It has not been possible positively to identify the originals of Walcott's drawings, which are partially restorations. For example, the exceptional holaspis (Pl. 116, fig. 10) is too small to be the original of Walcott's figure 14, if this be natural size as stated, but there can be little doubt but that this specimen was used. The illustrations given here are of some of the probable originals, and of other well-preserved examples. All are flattened in the shale, and the exoskeleton is preserved as a thin, light-coloured layer which readily flakes off the internal mould. This layer is presumably a replacement of the original mineral matter, and in some cases extends out beyond the margin of the fossil.

Degree 1 (Pl. 116, fig. 1).—The only good specimen lacks free cheeks, cranidium of length 0.64 mm. Glabella in front of occipital ring widens forward, first and second lateral furrows extend inward to one-third width of glabella, second lateral lobes have a low independent convexity. A broad, low ridge on the most anterior part of the fixed cheek is the palpebral lobe possibly combined with the eye ridge. Four distinct, and a faint fifth, pleural furrows are present on the transitory pygidium, and there is a broad median furrow behind the tip of the axis.

Degree 2 (Pl. 116, fig. 2).—The two thoracic segments are clearly seen, and part of the left free cheek protrudes from the rock as a narrow band. A second specimen shows the palpebral lobe at the anterior extremity of the fixed cheek. 5 pairs of pleural furrows on transitory pygidium, and median posterior

furrow. At left may be seen an emargination defining the tip of the anterior pleura, extended inward a short distance as an interpleural groove.

Degree 3 (Pl. 116, fig. 3,4).—Original of figure 3 is 1.94 mm. in length, of figure 4, 1.9 mm., both are better preserved than the original of Walcott's fig. 3, 1.76 mm. in length. Glabella widens anteriorly, there is a short occipital spine, first and second lateral lobes are well defined and each has independent convexity. Narrow anterior border clearly visible, merging laterally into most anterior part of the fixed cheek. Palpebral lobe is in the form of a narrow ridge, defined by a furrow, and situated opposite the posterior half of the frontal glabellar lobe. The faint depression that crosses the fixed cheek between the anterior end of the palpebral lobe and the axial furrow may mark the posterior edge of the eye ridge. Free cheeks not preserved. On the right of the original of Plate 116, figure 3, there appears to be a short spine, posteriorly directed, at the extremity of the posterior border. This might be a fixigenal spine, but seems more likely to be part of a displaced free cheek lying over the border. The postero-lateral angle of each pleura of the thorax, and of the five of the transitory pygidium, is drawn out into a short, blunt spine. The tip of the axis forms a sixth ring, and the pleural region behind it is subdivided by a median depression.

Degree 4 (Pl. 116, fig. 5).—Original of figure 5 is 2.1 mm. in length, and better preserved than the original of Walcott's Pl. 2, fig. 4, 2.25 mm. long. Cranidium like that of degree 3, and transitory pygidium with 5 or 6 pairs of pleural furrows and 6 or 7 axial rings.

Degree 5 (Pl. 116, fig. 6).—Length 2.7 mm. Independent convexity of first and second lateral glabellar lobes fainter and hardly visible after this degree. Transitory pygidium with median tubercle on first 3 axial rings, short pleural spines on pleurae of this region and of thorax.

Degree 6–15.—Walcott recognised specimens with from 6 to 13 thoracic segments, and I have found three in the collection with 14 segments, and one with 15, the latter 8.8 mm. in length. Specimens within this range of degrees are far less common in the collection than those of degrees 2–5, and three of the best-preserved examples are here illustrated (Pl. 116, fig. 7–9). During this part of the meraspid period the glabella becomes relatively wider, approaching the subsquare outline of the holaspis, and the posterior two lateral furrows extend close to the mid-line. The mid-point of the well-defined palpebral lobe is opposite the base of the second lateral glabellar furrow. Pleural spines of thorax reduced to blunt points, the tips of the posterior segments being rounded. Transitory pygidium relatively smaller, axis in late degrees with three rings and short posterior portion.

Holaspis.—Complete specimens rare, smallest 23.0 mm. in length (original of Plate 116, fig. 10), largest c. 52 mm. in length. The specimen illustrated is exceptional in that free cheeks are preserved, though pushed over the extremities of the fixed cheeks by the flattening the specimen has undergone. Free cheek with narrow well-defined border, continuous with anterior border, though border furrow does not continue across anterior branch of the suture and anterior part of the fixed cheek to join anterior border and axial furrows (Pl. 116, fig. 11). The cranidium (Pl. 116, fig. 12) also shows how posterior border furrow curves forward at extremity to run for a short distance just inside the posterior branch of the suture, and then dies out. Fixed cheeks at earlier degrees show this feature. Walcott (1879, Pl. 2, fig. 14) showed two additional pairs of short furrows on frontal lobe of glabella, one pair a short distance in front of the inner ends of the second lateral furrows, the second pair outside and in front of these. These furrows may be seen on a fragment of a cranidium, which also shows the palpebral lobe and lack of border furrow on fixed cheek (Pl. 116, fig. 11). These additional glabellar furrows are faintly visible in the original of Plate 116, figure 10 and cranidia in the collection. Only two specimens show the narrow, rolled cephalic doublure, but do not reveal the nature of the sutures which may cross them. The poorly preserved hypostome (Pl. 116, fig. 13) is shield-shaped, length about equal to breadth, small anterior wings and a raised region on the border posterolaterally.

Thorax of holaspis of 16 segments, each

axial ring with median tubercle, posterolateral tips of pleurae thickened and rounded. Axis of pygidium of 4 rings, anterior with median tubercle; 4 pairs pleural furrows and pleural region behind axis gently convex.

The cranidium of *Triarthrus caecigenus* Raymond (1925, p. 52–53, Pl. 2, fig. 16; see also Cooper, 1953, p. 8–9, Pl. 2, fig. 7–10; Pl. 19, fig. 4) has the posterior border furrow curving forward distally and running parallel to the posterior branch of the suture almost to the palpebral lobe. The latter is continued by a stout eye ridge to the axial furrow, and this eye ridge is defined on both sides by furrows, that on the anterior side being a border furrow. In my opinion this cranidium differs from that of *T. eatoni* principally in the presence of the well-defined eye ridge and border furrow on fixed cheek. I consider that there must have been an eye lobe, sutures, and narrow free cheek in *T. caecigenus* much as in *T. eatoni* (though in both cases they are rarely preserved in shale specimens), and not that eyes were absent and sutures ventral as Cooper suggested. The holotype has 13 thoracic segments. I consider Cooper's genus *Porterfieldia* a synonym of *Triarthrus*.

PROTASPIDES DESCRIBED BY BEECHER FROM THE FRANKFORT SHALE NEAR ROME, N.Y.

Two types of protaspis were described by Beecher from the "Utica slate, near Rome, New York." As Ruedemann has shown (1925, p. 53–62), this locality, famous for yielding trilobites with pyritised appendages, is at Six Mile Creek, near Rome, and is in the Frankfort shale which is slightly younger than the highest Utica shale. One of the protaspides, described below as Protaspis A, was referred by Beecher to the species of *Triarthrus* common in the Utica and Frankfort shales. Reasons for doubting this identification are given, but until developmental series of trilobites from the Frankfort shale are better known it is considered unwise to venture a new identification. The second protaspis, here described as Protaspis B, was considered by Beecher to be that of a species of *Proetus*, later named *P. beecheri* by Ruedemann. A size series of this protaspis is known, the smallest one previously undescribed, and I explain below why I question Beecher's identification and suggest that this protaspis is probably that of a phacopoid.

Protaspis A
Pl. 115 fig. 17–19

Description.—Five specimens of the protaspis attributed by Beecher (1893, 1895) to "*Triarthrus becki*" (or rather, following Ruedemann, 1925, 1926, *T. eatoni*), have been examined. Four examples are the originals of Beecher's illustrations, the fifth from his collection and deposited in the Museum of Comparative Zoology. Dimensions are as follows:

	Length	Length of Cephalon	Width at Occipital Ring
YPM 6664-A	0.7	0.45	0.49
YPM 6664-B	0.7	0.45	0.49
YPM 6597-B	0.7	0.47	0.49
YPM 6597-A	0.66	0.47	0.49
MCZ 2976	0.7	0.47	0.51

Glabella is parallel-sided, gently rounded in front, the short occipital ring with a faint median tubercle, and set off by a complete occipital furrow. In front of the furrow is a slightly longer (sag.) ring which may be indistinctly subdivided into two lateral lobes (Pl. 115, fig. 18), the first lateral furrows extending inward about one-third the width of the glabella. Faint second lateral lobes of similar size to the first suggested by convexities (Pl. 115, fig. 17,19). Third ring furrow most distinct medially, situated at a distance such that the three rings in front of the occipital are equal in length, and the anterior ring is longer. Gently convex fixed cheeks united in front of glabella by extremely short (sag.) preglabellar field, in front of which is shallow anterior border furrow and broad (sag. and exs.) anterior border. Palpebral lobe situated opposite point about one-third length of glabella, broad, faint eye-ridge curves inward to reach axial furrow in front of anterior ring furrow of glabella. Posterior margin of fixed cheek defined by shallow backward curving furrow. Lateral boundaries of fixed cheeks are sutural margins, gently curved, anterior branches convergent. Protopygidium with axis tapering back and reaching about two-thirds length, anterior ring may be clearly defined. Inner parts of pleural regions con-

vex, distally flattened and becoming concave in profile so that protopygidium has a broad border.

Discussion.—The specimens being all of about the same size, developmental stages of this protaspis cannot be distinguished, as Beecher claimed (1895, p. 172) they could, by size of protopygidium. The presence of the transverse furrow between cranidium and protopygidium indicates that all are late protaspides. That free cheeks are missing, and that the lateral boundaries of the cephalic portion are sutural boundaries, seems beyond question, especially if comparison be made with the protaspis of *Licnocephala cavigladius* (Ross, 1953, Pl. 63, fig. 1), from which the free cheeks are also missing. These two protaspides are exceedingly similar in form, that of Protaspis A differing in such details as presence of anterior cephalic border, eye ridges, depressed border of protopygidium, and subdivision and lobation of glabella. On the other hand, there are considerable difficulties inherent in regarding Protaspis A as an earlier stage of development of the original of Plate 116, figure 1, a Degree 1 example of *Triarthrus eatoni*. One would have to assume that changes that took place between late protaspis and degree 1 meraspis included expansion of the glabella anteriorly and changes in lobation, rapid reduction of preglabellar area, migration inward and forward of palpebral lobes, and loss of border in transitory pygidium. These are unlikely sounding changes when compared with the developmental changes observed in other species, notably this type of anterior glabellar expansion and a forward movement of eye lobes. It is far more likely that Protaspis A does not belong in *T. eatoni*. It may belong in a genus or family related to the bathyurid *Licnocephala*, and also resembles strongly proetid protaspides in collections from the Middle Ordovician of Virginia made by W. R. Evitt and me. It might, indeed, be the protaspis of *Proetus beecheri*, but other developmental stages of this species are unknown.

Protaspis B
Pl. 115, fig. 10,11,15,16,20

Description.—Three specimens of protaspides are preserved in the Yale collections, two of which were the originals of Beecher, 1895, p. 173–174, Pl. 9, fig. 5,6, and referred to "*Proetus parviusculus* Hall." Subsequently Ruedemann (1926, p. 129) placed these specimens in his "*Proetus*" *beecheri*. They may be described as follows:

YPM 6608 (Pl. 115, fig. 11,16).—Outline of shield subcircular, length 0.53 mm., median part flattened, lateral and posterior regions bent steeply down. Axis defined by deep furrows which commence in the deep anterior pits situated a short distance inside the anterior margin. Axis extends back to posterior margin, is widest at mid-length, from which point it tapers gently backward but more abruptly forward; divided into five rings. Anterior ring is the longest and the narrowest at its base, widening forward, and in front of the anterior pits it merges laterally into the large palpebral lobes. Succeeding four rings of about equal length, anterior of these widest posteriorly and with a median longitudinal groove, next posterior is widest ring of axis, succeeding two progressively narrower and faintly separated from each other, the posterior ring partly on steep posterior slope of shield and only faintly defined posterolaterally. Palpebral lobe is prominent ridge extending three-quarters of distance across anterior edge of cheek, defined on inner side by deep palpebral furrow, proximally connected by a lower, narrower ridge to the antero-lateral corner of anterior axial ring. Sutures must have run along margin in front of axis, and curved upward along outer edges of palpebral lobes and down to lateral margin, isolating tiny free cheeks. Pleural region of shield not subdivided, most convex adjacent to anterior pit.

YPM 6609 (Pl. 115, fig. 10,15).—Shield similar in outline and convexity to YPM 6608, but 0.7 mm. in length, and clearly divided into cephalon (0.49 mm. in length) and protopygidium. Glabella parallel-sided, defined by deep axial furrows posterior to the large anterior pits, divided into 5 rings by furrows which are deep circular pits beside the axial furrow and shallow medially. Occipital ring the shortest, with median tubercle, next three rings in front of equal length, anterior ring twice as long as that behind it, antero-lateral corner separated only by shallow depression (axial furrow in

front of anterior pit) from palpebral lobe Narrow (sag. and exs.) anterior border in front of glabella bearing 3 or 4 low tubercles. Large palpebral lobe extends across anterior edge of cheek, deep palpebral furrow. As in smaller specimen, sutures run along outer margin of anterior border and curve up along margin of palpebral lobes. Cheek is most convex in inner, anterior corner between palpebral lobe and glabella. Posterior border of cheek low, best defined by furrow which separates it from protopygidium. Axis of protopygidium tapering evenly to tip at posterior margin, first 2 rings visible. Pleural regions sharply flexed down at borders, anterior two pleural furrows present.

YPM 6671 (Pl. 115, fig. 20).—An incomplete but larger (length 0.94 mm.; cephalon 0.61 mm.) protaspis of the same type. Glabella of similar outline and subdivision, but ring furrows (except occipital) obsolete medially and frontal lobe rounded anteriorly and more distinctly outlined by shallow axial and preglabellar furrows. Anterior pits shallow. Anterior border wider (sag. and exs.), bearing row of 4 tubercles. Palpebral lobe relatively smaller, situated at anterolateral margin of cheek. On cheek posterolateral to palpebral lobe is low swelling which reaches to axial furrow opposite anterior lateral glabellar furrow. Posterior border well-defined and convex. Protopygidium with 3 axial rings and pleural furrows distinct.

Discussion.—It seems clear that these three specimens form a size series within a single species, preserved as internal moulds and hence not revealing any spines that may have been present around the margins. The smallest is unusual among described protaspides because of the pinching-in of the axis anteriorly. Such a constriction has been observed in tiny protaspides of *Pseudocybele nasuta* (Ross, 1951, p. 583, Pl. 82, fig. 1,2; Pl. 83, fig. 13–18), though in *P. nasuta* it occurs at the second ring from the anterior rather than at the base of the anterior ring. The form of the protaspis, subdivision of the axis, position of palpebral lobes, and course of sutures, is similar in the two species. The larger specimens in the Frankfort shale series resemble larger protaspides of *P. nasuta* (Ross, 1951, Pl. 82, fig. 3–13) in general characters—division of the glabella into 5 rings, the occipital short with median tubercle, the frontal the longest, presence of anterior pit and of large palpebral lobe at anterolateral edge of cheek, course of suture, cheek steeply sloping laterally, protopygidium subtriangular and with 3 or 4 axial rings and pleural pairs. These same general characters are seen in protaspides of phacopids (Temple, 1952; Whittington, 1956), certain cheirurids (Whittington and Evitt, 1954, p. 27) and *Flexicalymene* (Whittington, 1941, Pl. 72, fig. 1,2)—i.e. in phacopoids generally, and leads me to suggest that these three protaspides belong to a species within this superfamily. However, the only trilobites recorded from this locality are *Triarthrus eatoni*, *Cryptolithus bellulus*, and *"Proetus" beecheri* (Ruedemann 1925, p. 56). Other species of trilobites are not recorded from elsewhere in the Frankfort shale (Ruedemann, 1925, p. 53–62).

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JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 947–949, 1 TEXT-FIG., SEPTEMBER 1957

PENNSYLVANIAN REPTILES OF GARNETT, KANSAS: EDAPHOSAURS

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ABSTRACT—A new species of a small edaphosaurian reptile, *Edaphosaurus ecordi*, is described from an anterior thoracic vertebra occurring in the Upper Pennsylvanian near Garnett, Kansas. The genus is one of three typical pelycosaurs now known from the locality.

NEAR Garnett, Kansas, a fossil bearing shale in the middle of the Upper Pennsylvanian has produced the most complete record of reptilian life yet known from this period. In 1952, Peabody described in detail the the genus *Petrolacosaurus* represented by materials collected 20 years earlier by Drs. Henry H. Lane and Claude W. Hibbard, and attempted to reconstruct the environment represented by the extraordinary assemblage of plant and animal fossils from Garnett. The hope that much more material still remained to be recovered was fully realized in 1953 and 1954 by field parties of the University of Kansas Museum of Natural History (preliminary note, Peabody 1954). In addition to numerous tetrapod trackways, coelacanth fish, and a number of skeletons of petrolacosaurs, the parties discovered three other genera of reptiles. The bulk of the material was obtained from the west end of the shale exposures, where vertebrates had not been found previously (Walchia locality no. 1, Moore, et al., 1936, fig. 10). At present, nearly all the material is prepared and awaits description, delayed somewhat by the author's transfer from the University of Kansas to the University of California.

The author is extremely grateful to the Ecord family, especially Mrs. Ethel Porter of Garnett, and to the resident farmer, Mr. John B. Gates, for permission to excavate the fossils.

The reptiles from Garnett, other than petrolacosaurs, are clearly pelycosaurian and represent three distinct genera. One is close to if not actually the ophiacodont, *Clepsydrops*, and is represented by a nearly complete skeleton with articulated vertebral column and the skull (approx. 130 mm. long) and jaws, together with the disarticulated remains of a larger individual. A second genus, represented by a partial skeleton, is distinctly different from the first genus and appears to be a primitive sphenacodont. The third genus is clearly edaphosaurian, and is represented by a single, anterior thoracic vertebra (text fig. 1) and possibly by a half pelvis mistakenly referred to petrolacosaurs (Peabody 1952, fig. 5). It is obvious from these relatively excellent materials that pelycosaurian radiation was well along midway in the Late Pennsylvanian, and accordingly we must look for the actual dichotomy of pelycosaurian with basic reptilian stock much earlier, possibly deep in the Middle Pennsylvanian.

The edaphosaurian vertebra is complete enough and distinct enough to be described separately as a new species referable to the genus *Edaphosaurus*. Other genera will be described at a later time.

EDAPHOSAURUS ECORDI, n. sp.* (Pelycosauria: Edaphosauridae)

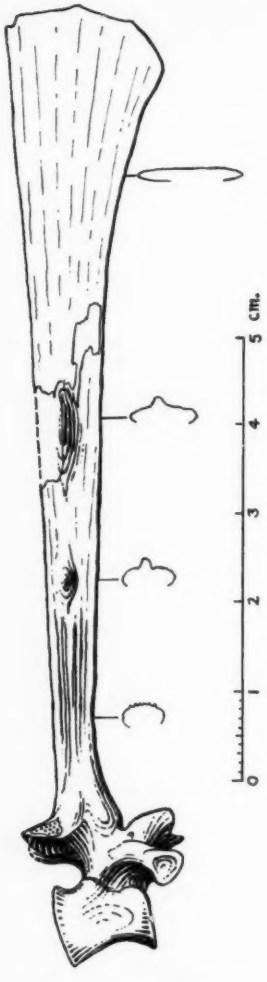
Text-fig. 1

Holotype: University of Kansas Museum of Natural History no. 9963; a complete anterior thoracic (or posterior cervical) vertebra, preserved with anteroposterior axis parallel to bedding plane, slightly distorted by crushing, and slightly damaged in the collecting.

Referred specimen: KUMNH no. 1425, Peabody 1952, fig. 5; a half pelvis.

Diagnosis: A tiny edaphosaur with thoracic

* Named in honor of the Ecord family who kindly gave permission to excavate on their land.



TEXT-FIG. *1*—Anterior thoracic (or posterior cervical) vertebra of *Edaphosaurus ecordi*, n. sp., from the Upper Pennsylvanian of Garnett, Kansas.

centrum 10 mm. long, a relatively enormous expansion of the distal one third of the long neural spine, and having only an incipient development of two tubercles on the side of the neural spine.

Description: The edaphosaur affinities of the vertebra are clearly shown by the elongate neural spine with expanded tip and lateral tuberculations, and by the lack of an excavation in the side of the neural arch.

Important measurements are:

length of centrum	1.05 cm.
greatest height of centrum	.95 cm.
bottom of centrum to dorsal edge of prezygapophysis	1.60 cm.
total height of vertebra	10.85 cm.
max. anteroposterior length of distal spine	1.70 cm.
max. anteropost. width of proximal shaft of spine	.50 cm.
height of centrum relative to total height of vertebra	8.9%

The centrum and neural arch are similar in comparable vertebrae of other species of *Edaphosaurus*. The zygapophyses have been crushed together and the stout transverse process pressed medially. The important characteristics are found on the neural spine. Proximally the spine is relatively slender and ovoid in section; here, vertical ridges less than 0.5 mm. broad appear to strengthen the shaft. A vertical groove, commonly found in edaphosaurs, running along the posterior margin of the spine is missing in our specimen. Near the middle of the shaft a small rounded tubercle and above it a vertically elongate tubercle break the otherwise smooth surface contour of the upper spine. There is some original crushing and also some damage during collection in this area, but the tubercles appear to be real structures, though small. Distally the spine becomes thin and blade-like with the anterior border sweeping up and forward until the maximum anteroposterior length is at least 3 times that of the proximal shaft and about 50% greater that the length of the centrum. Crushing no doubt accounts for part of the thinness of the blade but can not have increased the anteroposterior length significantly.

Immaturity of the vertebra may be indicated by a distinct break along what is normally in the adult the line of fusion between centrum and neural arch.

Discussion: Edaphosaurs are rare and of small size in the Pennsylvanian, and are represented only by fragments of vertebrae: *Edaphosaurus raymondi* from the Conemaugh group of strata in Pennsylvania is represented by a small fragment of a neural spine with a maximum diameter of 4 mm. (Romer 1940, p. 388); *E. mirabilis*, a European species from the late Stephanian of Czechoslovakia, is represented by a single dorsal vertebra lacking the distal-

most part of the spine and having a centrum approximately 10 mm. long (Romer 1940, p. 388; Case 1907, pl. 28, fig. 2). Another small form, *E. credneri*, from the Lower Permian of Germany, is represented by fragments of the postcranial skeleton characterized by relatively few and feebly developed cross bars (tubercles) on the neural spine, and a centrum approximately 10 mm. long in the dorsal region. Thus the Garnett species is clearly among the smallest and earliest of known edaphosaurs, and as a Pennsylvanian species, is represented by at least one complete vertebra. The neural spine is in all probability more blade-like at the tip, and has the weakest development (most primitive?) of lateral protuberances of any edaphosaur. As in other edaphosaurs, the Garnett species is least well represented among reptiles in the associated fauna.

There is the distinct possibility that the small, half pelvis mistakenly referred to petrolacosaurs (Peabody 1952, fig. 5) may be referred provisionally to our edaphosaur. The pelvis is the correct relative size, but was found over 800 feet away from the vertebra at site 3, toward the northeast end of the shale exposures (Moore, et al., 1936, fig. 10). Later finds of virtually complete skeletons of petrolacosaurs finally demonstrate the mistaken reference of the isolated pelvis (which was recognized at the time as having edaphosaurian characteristics). In lieu of any knowledge at the time of reptiles other than petrolacosaurs at Garnett, and because the pelvis was the correct size and stage of primitiveness, the conservative, and as it turned out, erroneous reference was made. Romer (personal communication) is of the opinion that the pelvis is certainly edaphosaurian. The extraordinary assemblage of tetrapods at the Garnett locality evokes caution in assigning the pelvis to *Edaphosaurus* because the general form of the pelvis is also suggestive of *Casea*. Until information to the contrary is available, however, it seems best to assign the pelvis provisionally to *E. ecordi*.

While additions to the paleoecological picture at Garnett are to be treated later, it may be said here that the edaphosaur vertebra was found within 6 inches of the bottom of a Pennsylvanian lagoon (see Peabody 1952, p. 37, for interpretation of deposits) in a near shore, or actual strand line facies. The vertebra is closely associated with an ophiacodont reptile similar to *Clepsydrops*, and lay in heavily carbonaceous shale containing a more typical, coalswamp flora than higher and off-shore deposits in the lagoon. This may or may not be significant because the referred pelvis occurred in relatively non-carbonaceous, limey shale resembling lithographic limestone, and in association with a Permian-like flora.

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SOME OSTRACODE HOMONYMS

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THE writer has recently come across several specific ostracode names which are objective homonyms. As some of them have been used repeatedly in literature it appears useful to give a short list with the purpose to invite criticism, to cause other students of Ostracoda to add their own observations on this subject, and to invite the original authors, if they are still living, or others who know the species concerned from their own work, to give these species new names.

A few cases of subjective homonymy have been added in which the homonymy appears to be indisputable.

OBJECTIVE HOMONYMS

Bairdia affinis BRADY, 1887 (p. 195, pl. 14, fig. 6,7) is preoccupied by *Bairdia affinis* MORRIS, 1845 (p. 291, pl. 18, fig. 10).

Bairdia brevis LIENENKLAUS, 1900 (p. 510, pl. 19, fig. 6) is preoccupied by *Bairdia brevis* JONES & KIRKBY, 1867 (p. 221). Key (1955, p. 106, pl. 15, fig. 1) has redescribed this species for which he proposes here the new name *Bairdia abbreviata* Key, A. J. Key told the writer that I. G. Sohn also informed him of this case of homonymy and invited him to rename the species.

Bairdia elongata LIENENKLAUS, 1900 (p. 509, pl. 19, fig. 5) is preoccupied by *Bairdia elongata* VINE, 1882 (p. 48) = *Macrocypris vinei* Jones. Key (1955, p. 106, pl. 15, fig. 3–4) has redescribed this species for which he proposes here the name *Bairdia longa* Key.

Bairdia rhomboidea JONES & SHERBORN, 1887 (p. 388) is preoccupied by *Bairdia rhomboidea* BRADY, 1869 (p. 162, pl. 19, figs. 14,15), which in turn is preoccupied by *Bairdia rhomboidea* KIRKBY, 1858 (p. 433, pl. 11, fig. 3,3a).

Bairdia ventricosa BRADY, 1890 (p. 2, pl. 4, fig. 17,18) is preoccupied by *Bairdia ventricosa* KIRKBY, 1858 (p. 326, pl. 10, fig. 3,3a).

Bythocypris elongata LEROY, 1943 (p. 358, pl. 59, fig. 13–16, text-fig. 2a) is preoccupied by *Bythocypris elongata* BRADY, 1880 (p. 47, pl. 6, fig. 1a–c).

Cypridea ventosa JONES, var. *bispinosus* VANDERPOOL, 1928 (p. 104, pl. 14, fig. 1,2) is preoccupied by *Cypridea bispinosa* JONES, 1878 (p. 109).

Cythere oblonga ZALÁNYI, 1944 (p. 66, pl. 7, fig. 5–11, pl. 8, fig. 9, text-fig. 39–42) is preoccupied by *Cythere oblonga* MCCOY, 1844 (p. 167, pl. 23, fig. 22).

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Cytherideis cylindrica ULRICH & BASSLER, 1904 (p. 126, pl. 37, fig. 17) is preoccupied by *Cytherideis cylindrica* BRADY, 1869 (p. 113, pl. 13, fig. 11,12).

Cytheropteron coryelli PURI 1953b (p. 42, pl. 4, fig. 13–15, text-fig. 6e) is preoccupied by *Cytheropteron* (*Cytheropteron*) *coryelli* SCHMIDT, 1948 (p. 413, pl. 62, fig. 11,12).

Cytherura alata G. W. MÜLLER, 1894 (p. 188, pl. 18, fig. 1,7,8) is preoccupied by *Cytherura alata* LIENENKLAUS, 1894[1] (p. 241, pl. 16, fig. 10a–c).

Cytherura reticulata G. W. MÜLLER, 1894 (p. 298, pl. 17, fig. 12,13, pl. 19, fig. 17) is preoccupied by *Cytherura reticulata* LIENENKLAUS, 1894[1] (p. 242, pl. 16, fig. 11a,b).

Cytherura sulcata LIENENKLAUS, 1905 (p. 55, pl. 4, fig. 19) is preoccupied by *Cytherura sulcata* G. W. MÜLLER, 1894 (p. 297, pl. 17, fig. 4,10).

SUBJECTIVE HOMONYMS

Cytherella truncata BRADY, 1869 (pl. 154, pl. 19, fig. 3,4) is a subjective homonym of *Cythere truncata* BOSQUET, 1847 (p. 7, pl. 1, fig. 2a–e) which species was assigned to *Cytherella* first by Bosquet (1854), who thought it identical with *Cytherella munsteri* (Roemer), later as a separate species by Van Veen, 1932 (p. 22, pl. 5).

Pontocypris obtusa LIENENKLAUS, 1900 (p. 507, pl. 19, fig. 2) is a homonym of *Erythrocypris obtusa* G. W. MÜLLER, 1894 (p. 257, pl. 11, fig. 3,4,28–32) since *Erythrocypris* is a synonym of *Pontocypris* Sars.

Xestoleberis longissima SCHMIDT, 1948 (p. 411, pl. 63, fig. 11–13) has been assigned by Puri (1953a, p. 750) to *Cytherideis*. In doing so he made it a homonym of *Cytherideis longissima* MÉHES, 1941 (p. 24, pl. 6, fig. 9–11), text-fig. I–4,27 (III–62).

As *Cytherideis* has no standing as a generic name, since it is a synonym of *Cypridea* (see Sylvester-Bradley & Harding, 1953), the homonymy is disputable in case the two species should prove to belong to different genera. However, it is quite possible that both will be assigned eventually to the same genus.

Xestoleberis pusilla ELOFSON, 1941 (p. 341, text-fig. 22–25) could be a homonym of *Bairdia pusilla* EGGER, 1858 (p. 409, pl. 1, fig. 7) which has been assigned to *Xestoleberis* by Neviani (1928, p. 41, pl. 1, fig. 20–22).

Xestoleberis subglobosa LIENENKLAUS, 1900 (p. 533, pl. 21, fig. 7) is probably a homonym of *Bairdia subglobosa* BOSQUET, 1852 (p. 23, pl.

[1] Lienenklaus's paper appeared in Heft 1 of the Zeitschr. Deutsch. Geol. Gesell., v. 46, 1894, which bears the date Januar-März. The introduction to Müller's Flora and Fauna des Golfes von Neapel bears the date Juli 1894. Therefore it is almost certain that Lienenklaus's paper was published earlier than Müller's.

1, fig. 7a–d) which species belongs to *Xestoleberis* according to Apostolescu (1955, p. 260).

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MANUSCRIPT RECEIVED DECEMBER 16, 1956

JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 952–954, PL. 117, SEPTEMBER 1957

PTERODACTYL TRACKS FROM THE MORRISON FORMATION

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ABSTRACT—A peculiar trackway discovered in the Salt Wash member of the Morrison formation in the Carrizo Mountains, Arizona, near the Four Corners has been proved to pertain to a pterodactyl. This is the first recorded discovery of flying reptile tracks and the second known indication of the group in the North American Jurassic. The specimen proves that pterodactyls could assume the quadrupedal pose and method of locomotion.

INTRODUCTION

IN JUNE, 1952, while engaged in a study of uranium deposits in the Carrizo Mountains district in Apache County, Arizona, the writer discovered a series of footprints of a pterodactyl in the Salt Wash member of the Morrison formation. The locality is 16.5 miles S. 57° W. of the well known Four Corners, on the west side of Sah Tah Wash, a relatively broad, shallow canyon cut in the Morrison formation and older sediments.

The track-bearing unit is a 2 to 4 inch thick stratum of medium-grained, brownish-gray sandstone. It is distinctly lenticular and pinches out entirely in one direction a few feet from the side of the trackway. It is faintly ripple marked on the upper surface and there are current lineations and elongate markings indicating that the sandstone was a small sand bar lying parallel with a flowing stream of water. From the position of the tracks, their degree of indentation and the apparently unsteady gait of the pterodactyl, it is inferred that the creature was walking parallel to and near the edge of a stream in moist to very moist sand.

Above the tracks is a thin stratum of mudstone which covers and fills them. Evidently conditions were such that the water rose very slightly and under relatively quiet conditions deposited a mud layer which preserved the tracks from destruction.

In order to obtain all possible prints it was necessary to remove considerable overburden. From the fact that the track-bearing stratum apparently thins out entirely near the end of the excavation, it is assumed that no additional tracks exist beyond those removed.

DISCUSSION

Owing to the fact that practically all known pterodactyl fossils have been found in connection with marine beds such as the Solenhofen lithographic limestones and the Jurassic and Cretaceous formations of England, there has been a tendency on the part of paleontologists to relate flying reptiles to the oceanic environment. Thus, they are commonly pictured as gliding over the water or clinging to cliffs near the shore. The idea that they were fish eaters has also become strongly embedded in the literature. How they could have managed to catch fish as food is somewhat of a mystery, for they would have to make their catch as the fish momentarily emerged from the water. Such an action taxes even the most agile sea birds and is scarcely creditable for an animal which probably could not touch the water or maneuver rapidly above it.

The present specimen furnishes a basis for added speculations on the life habits of pterodactyls. Northeastern Arizona in the Jurassic period was about as far from an ocean as it was possible to get at that particular time. It seems safe to assume that the track making form was totally adapted to life on a broad alluvial plain. The Salt Wash terrain is visualized as semi-arid with broad inter-river tracts of sterile sand and dried mud. The vegetation appears to have been confined chiefly to river banks and there were patches of relatively large trees, remains of which are now found silicified and also replaced by uranium minerals. The large fossil logs have been identified as the coniferous genus, *Araucarioxylon*, a form still extant in the Southern Hemisphere. It is a tree noted for the straightness of the

trunk and the fewness of the branches, which are clustered near the top. Smaller shrub-like plants are indicated but a general forest growth was certainly not present. The rivers were of moderate size and were subject to great fluctuations in volume and sudden changes in course.

From the nature of its indicated habitat, the Salt Wash pterodactyl is more likely to have eaten insects or seeds than fish. There is no evidence of nearby cliffs from which it could have glided forth on food gathering forays. Much more plausible is the idea that it was essentially a tree form. The claws of both the fore and hind feet, especially the peculiarly recurved ones of the latter, seem well adapted for progress over rough bark. The hind foot resembles that of certain bats with the curved claws adapted for hanging from branches and other rough surfaces.

The pterodactyl may be visualized as spending much of its time in the trees, a habitat for which there were few challengers in late Jurassic time. On occasion, with ascending air currents, it might soar over adjacent territory or to nearby trees. If forced to land on level ground, it had only to walk to the nearest tree which it would climb to again become airborne when conditions were favorable.

The present specimen proves that at least one kind of pterodactyl had the quadrupedal mode of walking. The prints of manus and pes are both clearly marked. The pes marks are turned slightly outward but there is no evidence that the knees pointed outward or that there was anything awkward about the position of the hind leg in relation to the body while walking.

This is the first proved discovery of pterodactyl tracks recorded. It is also the second fossil indication of the group from the Jurassic of the Western Hemisphere. The only other fossil pterodactyl known in the American Jurassic is *Dermodactylus montanus* represented by a few bones from the Morrison formation of Wyoming (Marsh, 1878).

PTERODACTYLOIDEA (REPTILIA: PTEROSAURIA)

Genus PTERAICHNUS, n. gen.

Aerial quadruped. Manus with 3 digits, 2 of which are small and bear short, blunt claws; the third, very much larger, supports the wing membrane and is capable of being bent backward and upward so as to leave only a short trailing impression. The pes has 4 digits. The heel is very narrow, the sole V-shaped and the toes slender with curving claws. The inferred length of the body exclusive of neck, head and tail, about 30 inches. In walking, the hindfoot oversteps the forefoot indicating a short body and perhaps the possibility of occasional bipedal stance. The apparent reduction of digits in both manus and pes is distinctive and is the chief reason for placing the animal in the Pterodactyloidea.

Type species.—*Pteraichnus saltwashensis*, n. sp.

PTERAICHNUS SALTWASHENSIS, n. sp.

Pl. 117, fig. 1–3

Type specimen.—A trackway consisting of 9 pairs of consecutive footprints on 4 slabs of sandstone, collected by Wm. Lee Stokes, 1952. Mounted for exhibit in the Geology Museum, University of Utah.

Locality.—Northwest flank of Carrizo Mountains, Apache County, Arizona; unsurveyed territory about 16.5 miles southwest of the Four Corners.

Geologic horizon.—Middle of Salt Wash sandstone member of Morrison formation, Late Jurassic.

Trackway.—The preserved trackway consists of 9 consecutive steps. The first three are clearly preserved, the last 6 which were made in softer and more uneven ground are poorly preserved. Associated with the track are several obscure grooves which may have been made by the trailing edge of the wing or by the pteroid bone as the creature walked unsteadily through the mud. The stride as determined from the more uniform tracks is 28 inches but it is distinctly less in the unsteady tracks. The pace angulation ranges between 105° and 115° in the better sets of prints.

Manus.—The manus reflects the unique adaptations of the pterodactyl wrist and hand. The impression is essentially tridactyl with prints of two short digits and the long wing-bearing member. Marks of all three digits radiate from a deep central depression, which must mark the knuckle joint between the heavy metacarpal bone and the wing-bearing digit. The two smaller digits

bear short but pointed claws, which made impressions that turn outward more or less parallel with the surface of the stone. There is no sign of a third small digit, which, so far as known to the writer, is found in all well preserved pterodactyl skeletons. The length of the total manus impression varies with the different prints but averages about $3\frac{1}{4}$ inches. The length of the impressions of the shorter digits is 1 to $1\frac{1}{2}$ inches.

Pes.—The pes has a distinct V-shape with a sharply pointed heel, well marked flat sole and 4 diverging toes of almost equal length. This shape corresponds unmistakably with the bone structure of known pterodactyl skeletons and with the feet of the larger living bats. There is no sign of the 5th toe which is complete and well formed in *Rhamphorhynchus* and represented more or less completely in other pterodactyls. If present at all is should have made some sort of impression in the heel region. The curvature of the toes, especially the outer one, is striking. The smaller and possibly weaker toe has left an impression parallel with the stone and has the claw pointed inward. The other toes apparently are also curved but in most of the impressions they did not turn sidewise but made only pointed impressions. In the softer sand all toes have turned downward and inward emphasizing the tendency to curl or curve. This may indicate the adaptation for climbing and clinging shown in parallel fashion by the bats.

The total length of the pes is 3 inches. The divarication of the outer and inner impressions of the foot is 40°.

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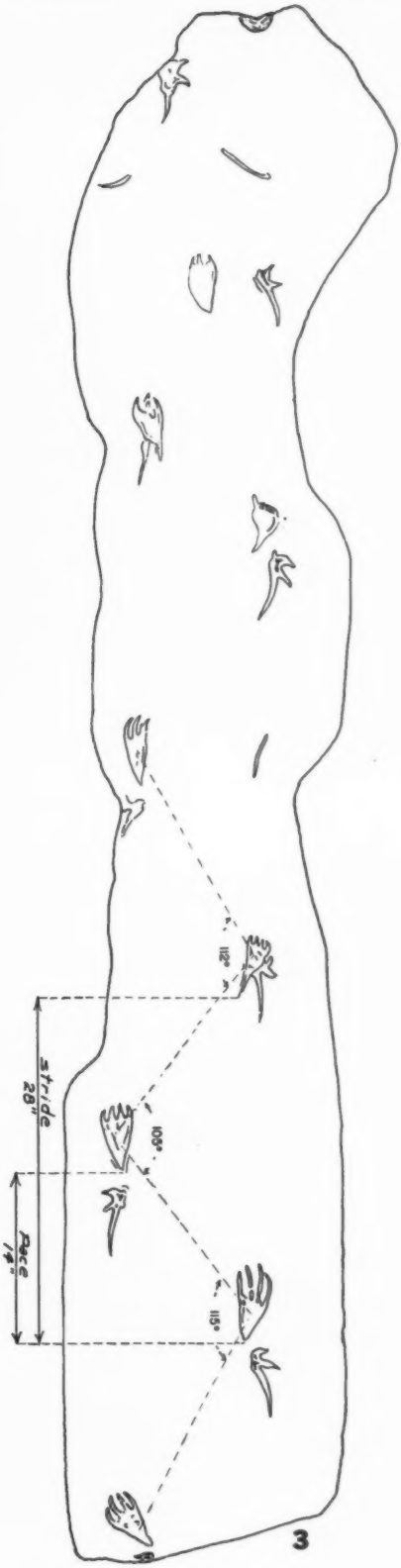
MANUSCRIPT RECEIVED FEBRUARY 7, 1957

EXPLANATION OF PLATE 117

FIG. *1*—Three rock slabs showing four consecutive sets of footprints of *Pteraichnus saltwashensis*.
2—Detail of the best pair of prints.
3—Sketch of entire trackway showing essential measurements.

1

2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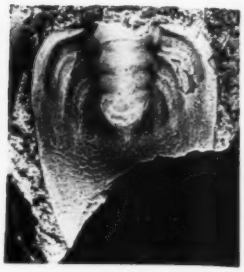
28"
Pace
14"
112°
103°
115°
3

1

2



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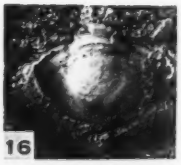
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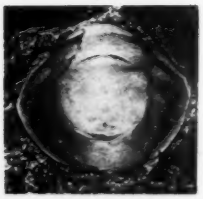
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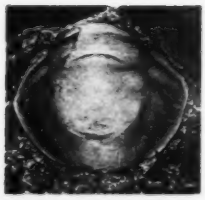

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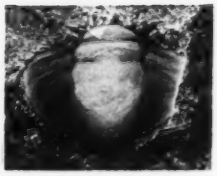

JOURNAL OF PALEONTOLOGY V. 31, NO. 5, P. 955–972, PL. 181–221, 4 TEXT-FIG., SEPTEMBER, 1957

ADDITIONAL FOSSILS FROM THE MIDDLE CAMBRIAN MT. WHYTE FORMATION OF THE CANADIAN ROCKY MOUNTAINS

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ABSTRACT.—Field work in 1955 revealed new fossiliferous beds in the section of the Mt. Whyte formation on Mt. Field, British Columbia. Two new faunules, and several fossils from previously known faunules, are discussed and illustrated. The Mt. Field section provides the most varied and complete faunal succession of the *Plagiura-Kochaspis* zone known anywhere. Six new species of trilobites and two new species of gastropods are described. In addition, unnamed forms of trilobites, gastropods, and organisms of uncertain affinities are illustrated. Internal structures in gastropods and in the problematic genus *Stenothecoides* are figured and discussed. Three new trilobite genera are proposed: *Loxopeltis* (type, *L. problematica*, n. sp.); *Onchocephalites* (type, *O. laevis*, n. sp.); and *Parapoulsenia* (type, *P. lata*, n. sp.).

THE Mt. Whyte formation of Alberta and British Columbia has so far supplied most of the available information on the fauna of the early Middle Cambrian *Plagiura-Kochaspis* zone (Rasetti, 1951). Hence new field work appeared desirable in order to increase our knowledge of this fauna. The area was again visited in the summer of 1955, thanks to a grant from the Penrose Bequest of The Geological Society of America. The author expresses his great indebtedness to the Society for making this work possible.

An additional stimulus to the investigation of those strata was the hope of further discoveries of specimens of *Scenella* and *Stenothecoides* preserving internal features (Rasetti, 1954). Although particular care was devoted to the collection of these non-trilobitic fossils, the results were disappointing, as only one specimen of *Stenothecoides* with well-preserved internal structures was discovered, and none of *Scenella* that could add to the information gathered from previously known material. On the other hand, good collections of two species of coiled gastropods were made, and observations on sectioned specimens revealed interesting details.

THE MT. FIELD SECTION

Most of the fossils described herein were collected from the Mt. Field section, although specimens from other localities are occasionally discussed. Since two new fossil horizons were discovered in that section,

EXPLANATION OF PLATE 118

All figured specimens preserve the test unless otherwise indicated. Only one photograph of each stereogram pair is numbered.

FIG. *1–8—Fieldaspis celer* (Walcott), ×2. *1*, Cranidium. *2,5,6*, Pygidia. *3*, Lateral view of hypostoma. *4*, Segment from posterior part of thorax. *7*, Largest cranidium observed. *8*, Free cheek. Locality W28fg; G.S.C. 13538a–h, plesiotypes.

9–16—Dolichometopsis? sp. undet. *9,10*, Partly exfoliated cranidia with parallel-sided glabella and narrow palpebral area, ×3. Locality W4d, Ross Lake; G.S.C. 13541. *11*, Cranidium similar to the preceding, ×3. Locality W7f, Mt. Field; G.S.C. 13540. *12*, Cranidium with expanding glabella and wider palpebral area, ×3. Locality W7f, Mt. Field; G.S.C. 13539b. *13*, Cranidium with expanding glabella, wide and flat palpebral area, and well-preserved occipital spine, ×3. Locality W28fg, Mt. Field; G.S.C. 13539a. *14*, Pygidium possibly belonging to the above cranidia, of the type with narrow pleural lobes. ×5. Locality W28fg, Mt. Field; G.S.C., 13542a. *15*, Pygidium with wide pleural lobes, ×5. Locality W28f, Mt. Field; G.S.C. 13544a. *16*, Pygidium intermediate in shape between those shown in figures *14* and *15*, ×5; locality W28f. Mt. Field; G.S.C. 13544b. See also plate 119.

and additional collections of the previously known faunules were made, it is opportune briefly to describe the section and list the fossils present at the various levels.

The main section, given as No. 7 in the previous paper (Rasetti, 1951) is located immediately east of the Kicking Horse mine on the southeast slope of Mt. Field. In 1955 the strata were also examined at the easternmost exposure of the Mt. Whyte formation, about one-quarter mile east of the Kicking Horse mine. Here only the upper part of the formation is exposed, the rest being covered by talus. From this supplementary section, designated herein by the number 28, fossils were collected at three levels, labeled W28ef, W28f, and W28fg. The faunule collected at the last and highest of these levels is interesting, because in the old section no fossils were collected in the interval between the fossiliferous levels W7f and W7g. In section 7, rich fossil beds, labeled W7ef, were discovered below the old beds W7f. A summary description of the section combining the old and new information follows.

Middle Cambrian

	Feet
Mt. Whyte formation (section No. 7, supplemented by section No. 28)	
Limestone: finely crystalline, hard, black-gray, in beds 1–3 inches thick; top portion irregularly dolomitized. Fossils collected 40–50 feet above base (W7g). Beds W28fg are presumably equivalent to strata 20–22 feet above the base of this interval	110
Limestone: crystalline or oolitic, dark gray, in beds 1–3 inches thick	5
Limestone: crystalline or oolitic, dark gray, with tan clay partings and flakes, in beds 1–2 inches thick; more shaly in lower portion. Fossils collected 72 feet above base (W7f), 60 feet above base (W7ef), 10 feet above base (W7e), and 1–2 feet above base (W7d); also at undetermined horizons within unit (W7, W7f'). Beds W28ef and W28f are approximately equivalent to W7ef and W7f, respectively	75
Shale: siliceous, banded gray and tan. Top of interval forms bench in cliff, crossing portal of Kicking Horse mine a little above floor. Base of unit and Mt. Whyte-St. Piran contact covered by talus. Fossils in thin limestone layers in top 3 feet of interval (locality W7c)	105+

The fossils collected from all beds mentioned in this section are listed in Table 1. An indication of the frequency of each species is given by the letters rr=very rare, r=rare, c=common, cc=very common. An x indicates presence of the species when the collection is too small to allow an estimate of the frequency.

In addition to the fossils listed, the collections included a species of *Hyolithes;* cylindrical tubes probably referable to *Coleoloides;* and 3 species of brachiopods, *Nisusia* sp., *Wimanella* sp., and an inarticulate (cf. *Paterina*). These organisms are left out of consideration, since their description would not add significantly to the knowledge of their morphology or stratigraphic distribution.

Localities other than those in the Mt. Field section are designated by the same abbreviations as in the previous paper (Rasetti, 1951) and hence their position in the respective sections is not reported in detail.

DISPOSITION OF TYPES

Types of new species and other figured specimens were deposited in the collections of the Geological Survey of Canada (G.S.C).

SYSTEMATIC DESCRIPTIONS

TRILOBITA

Superfamily CORYNEXOCHOIDAE

Family DOLICHOMETOPIDAE Walcott

Genus FIELDASPIS Rasetti, 1951

FIELDASPIS BILOBATA Rasetti

Pl. 121, fig. 12,13

Fieldaspis bilobata Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 161, pl. 16, fig. 1–7.

A complete exoskeleton flattened in shale from the type locality is figured in order to show the general aspect of this trilobite. The thorax has 9 segments, as in the type species, *F. furcata.*

A single, immature pygidium apparently belonging to this species was collected from the Mt. Field section.

Horizon and locality.—The type locality is W20d, Eiffel Peak, Alberta. The pygidium figured herein is from locality W7ef, Mt. Field.

Types.—Holotype: U.S.N.M. 116146.

TABLE 1.—SPECIES OCCURRING AT VARIOUS HORIZONS IN THE MT. FIELD SECTION OF THE MT. WHYTE FORMATION

Horizon	W7c	W7d	W7e	W7ef	W28ef	W7f	W28f	W28fg	W7g
Trilobita									
Alokistocare cleora (Walcott)	x	x		r	c	r	x	r	
Caborcella rara Rasetti									r
"Dolichometopsis" sp. undet.				rr		r		rr	
Fieldaspis bilobata Rasetti				rr					
celer (Walcott)								cc	
furcata Rasetti	x		c	c	c	cc	cc		
superba Rasetti									c
Kochiella? gibbosa Rasetti, n. sp.			rr		rr	rr		r	
maxeyi Rasetti				c	r	rr	r	r	
Kochaspis eiffelensis Rasetti				c	r	r		c	
Loxopeltis problematica Rasetti, n. gen., n. sp.								rr	
Onchocephalus depressus Rasetti									c
fieldensis Rasetti	x	x			c	cc	c		
maior Rasetti				r	r	c			
skapta (Walcott)	x	x	c	c	r		r		
cf. *skapta* (Walcott)								rr	
sublaevis Rasetti									r
Onchocephalites laevis Rasetti, n. gen., n. sp.								r	
Oryctocephalites resseri Rasetti				rr		rr			
Parapoulsenia lata Rasetti, n. gen., n. sp.				c					
Plagiura cercops (Walcott)			r	r	r		c	r	
Poulsenia columbiensis Rasetti, n. sp.					rr				
Schistometopus convexus Rasetti			c	cc	c	r	r	c	
Schistometopus? minor Rasetti, n. sp.				r				rr	
Gastropoda									
Helcionella? carinata Rasetti, n. sp.				c				r	
insulcata Rasetti, n. sp.				r		r	r	r	
sp. undet.						rr			
Scenella? sp. undet.				c	c	c	c	c	
Phylum undetermined									
Stenothecoides cf. *elongata* (Walcott)				c	c	c	c	c	

Paratypes: U.S.N.M. 116147. Plesiotypes: G.S.C. 13536–7.

FIELDASPIS CELER (Walcott)
Pl. 118, fig. 1–8; text-fig. 4

Crepicephalus celer Walcott, 1917, Smithsonian Misc. Coll., v. 67, no. 3, p. 101, pl. 11, fig. 2.
Kochaspis celer (Walcott) Resser (part), 1935, Smithsonian Misc. Coll., v. 93, no. 5, p. 36.
Fieldaspis celer (Walcott), Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 110.

As the writer had suspected in 1951, the pygidium described by Walcott as *Crepicephalus celer*, which Resser united with a ptychopariid head to form a species of *Kochaspis*, has no ptychopariid affinities, but belongs to a species of *Fieldaspis* which turned out to be exceedingly common at the new locality W28fg. Scores of excellently preserved parts of the exoskeleton were recovered. The species is so similar to the type species of the genus, *F. furcata* Rasetti, that only the differential characters, and details not previously observed in the latter species, are mentioned.

The cranidium, free cheeks, hypostoma and thorax appear indistinguishable from the corresponding parts of *F. furcata*, except that *F. celer* seems to attain a larger size. The largest cranidium of *F. celer* has a length of 21 mm., while the largest cranidium of *F. furcata*, among the hundreds observed, only attains a length of 14 mm. The pygidia are proportionately larger.

In preparing hypostomas of *F. celer*, a

feature also present in *F. furcata*, but not previously noticed because generally obscured by the matrix, was observed. This is the pair of upward directed wing processes, also present in many post-Cambrian trilobites (Whittington and Evitt, 1954). The wing process presumably exists in the similar hypostomas of other dolichometopid trilobites, but would usually escape observation because when the hypostoma is exposed from the convex (ventral) side, the process sinks vertically into the matrix. Exposure of the process usually leads to breakage of the "anterior wing."[1] The structure of the hypostoma is shown in text-figure 4.

The pygidium has the general structure of *F. furcata*, differing in the straighter lateral outline and the longer and more sharply pointed posterior marginal spines. There is a considerable degree of variability in these characters, even among pygidia of the same size, some of them being intermediate between *F. furcata* and the type of *F. celer*. Immature pygidia are often indistinguishable, approximating in either species the shape observed in the adult of *F. furcata*. This is one of those cases, common in paleontology, where two non-contemporaneous populations are distinguishable statistically, although not always from single individuals, and it is entirely arbitrary whether we call them separate species or not. It is also clear that no great difference separates these two forms from *F. superba* of still higher beds, and we can confidently assume that the series *furcata-celer-superba* represents a line of evolution in *Fieldaspis*, characterized by the lengthening and sharpening of the pygidial spines. It is possible that *F. bilobata* is the ancestor of this lineage.

Horizon and locality.—The type locality is U.S.N.M. 58k, Mt. Whyte formation, Mt. Stephen. The plesiotypes figured herein were collected at locality W28fg, Mt. Field.

Types.—Holotype: U.S.N.M. 64367. Plesiotypes: G.S.C. 13538.

[1] The term "anterior wing" is placed in quotation marks because this portion of the hypostoma here represents the fused rostrum, hence is not homologous with the anterior wing of the ptychopariids and most of the post-Cambrian trilobites which have a separate rostrum.

Genus DOLICHOMETOPSIS Poulsen, 1927

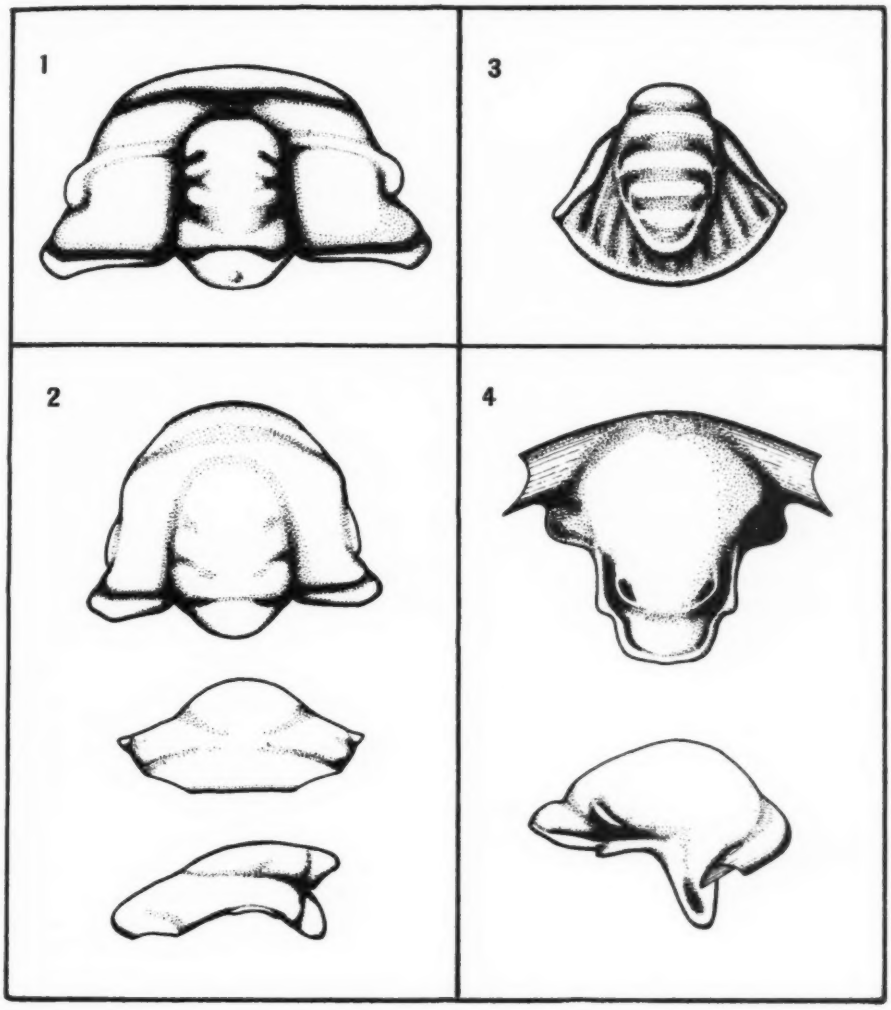
DOLICHOMETOPSIS? sp. undet.

Pl. 118, fig. 9–16; Pl. 119, fig. 12–15

Cranidia and pygidia which occur in the *Plagiura-Kochaspis* zone of the Mt. Whyte formation at several localities, but are rare everywhere, are tentatively associated and doubtfully assigned to *Dolichometopsis*. The cranidia are generically indistinguishable from this genus or *Ptarmigania*. The pygidia are quite distinctive and, if they belong to the cranidia, the association would require a new generic name. Although several species seem to be represented in the collection, no separation can be attempted owing to the scarcity of the material and the uncertain assignment of cranidia and pygidia.

About a dozen cranidia were collected, and the 5 best preserved are figured. The glabella is long, prominent, and more or less expanded anteriorly, almost reaching the anterior margin of the cranidium but for an exceedingly narrow (sag.) border. Four pairs of glabellar furrows are impressed. Occipital furrow deep laterally and shallow medially; occipital ring extended into a long spine. Palpebral area flat in some specimens, convex in others, ranging from less than one-third to about one-half the glabellar width at the same level. Palpebral lobes narrow, from one-third to one-half as long as the glabella, continuous with the short ocular ridge. Anterior area of the fixed cheeks well developed only laterally, of varying width (tr.), from about one-fifth to one-third of the anterior width of the glabella. Posterior area, where preserved, slender and wide (tr.). Possibly the figured cranidia could be grouped into two species, those with less expanded glabella, narrower palpebral area and smaller palpebral lobes (pl. 118, fig. 9–11) representing one species, and the others (pl. 118, fig. 12,13) a second species. However, there are variations even within each group, hence it seems best not to attempt defining species until more material becomes known. The surface of the test is smooth or very finely granulated.

The pygidia are equally rare but were collected from most of the localities where the cranidia occur. Two such pygidia were previously figured (Rasetti, 1951, pl. 15, fig. 10,11) and tentatively placed in the



TEXT-FIG. *1–4*

1, *Parapoulsenia lata* Rasetti, n. gen., n. sp. Cranidium, ×8.
2, *Onchocephalites laevis* Rasetti, n. gen., n. sp. Cranidium in dorsal, frontal, and lateral views, ×8.
3, *Loxopeltis problematica* Rasetti, n. gen., n. sp. Pygidium, ×5.
4, *Fieldaspis celer* (Walcott). Ventral and lateral views of hypostoma, ×4.

family Dolichometopidae. They are characterized by a wide axis, well defined laterally but gradually sloping down posteriorly, and narrow, transversely concave pleural lobes. The relative width of the axis and pleural lobes, the width-length ratio for the entire pygidium, the degree of concavity of the pleural lobes, and other details vary considerably from one specimen to another. Several characteristic shapes are illustrated. Possibly these pygidia could be grouped into two forms, one with narrow pleural lobes (typified by the specimen illustrated in plate 118, fig. 14, and by the two specimens figured in Rasetti, 1951) and a second form with wide pleural lobes, less common than

the preceding, typified by the specimen represented in plate 119, fig. 13.

If these pygidia belong to any of the known cranidia from the same beds, there seems no other solution than to associate them with the above described cranidia of "*Dolichometopsis*," as it is very unlikely that they represent ptychopariid trilobites.

Horizon and locality.—Cranidia were collected at localities W4d, Ross Lake; and W7f, W7ef, W28fg, Mt. Field. Pygidia were collected at localities W4d, Ross Lake; W20d, Eiffel Peak; and W7c, W7f, W7ef, W28f, W28fg, Mt. Field. Also pygidia from U.S.N.M. locality 38k, identical with locality W20d.

Figured specimens.—Cranidia: G.S.C. 13539–41. Pygidia: G.S.C.: 13542–44.

Undetermined pygidium No. 1
Pl. 120, fig. 12

This pygidium almost certainly belongs to a dolichometopid trilobite, but the corresponding cranidium has not been found, unless it be one of the species of *Dolichometopsis?* previously described. Only two specimens are known.

Pygidium subrectangular. Axis occupying little more than half of the length and about one-third of the width, tapered, prominent, with three distinct pairs of furrows more deeply impressed at the sides. Pleural lobes concave both transversely and longitudinally, with faint indication of two pairs of broad furrows curving backward to a longitudinal course. Pleural margin with two pairs of short, flat, broad spines; a rather shallow median notch separates the spines of the posterior pair. Length of pygidium 5 mm.

Although this pygidium cannot be assigned to any described genus, it does not seem proper to name a new genus in the absence of a cranidium. Some resemblance to the pygidia of *Stephenaspis* is possibly indicative of affinity.

Horizon and locality.—W7f, Mt. Field.
Figured specimen.—G.S.C. 13546.

Family Oryctocephalidae Beecher
Genus Oryctocephalites Resser, 1939
Oryctocephalites resseri Rasetti
Pl. 119, fig. 1,2

Oryctocephalites resseri Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 196, pl. 19, fig. 9.

Two additional cranidia and one pygidium of this rare species were collected.

A feature of the cranidium not previously reported is the presence of a pair of slender intergenal spines, clearly visible on the photograph reproduced herein.

The pygidium was previously unknown. It differs from the pygidium of *O. typicalis* Resser in bearing only 3 pairs of large and one pair of small marginal spines. The spines of the last pair are close to each other and directed slightly upward. The posterior end of the axis is marked by the axial furrow, but the axis does not rise above the posterior portion of the pleural lobes. The axis shows three furrows in addition to the articulating furrow. The pleural lobes have three pairs of well-impressed pleural furrows and two pairs of shallow interpleural grooves.

Horizon and locality.—The types are from locality W7f, Mt. Field. The specimens figured herein are from locality W7ef, Mt. Field.

Types.—Holotype: U.S.N.M. 116139. Paratype: U.S.N.M. 116140. Plesiotypes: G.S.C. 13547.

Superfamily Ptychopariioidae

Since many ptychopariids cannot yet be satisfactorily assigned to familes, the genera are placed in alphabetic order as in the previous paper (Rasetti, 1951).

Genus Kochaspis Resser, 1935
Kochaspis eiffelensis Rasetti, 1951
Pl. 119, fig. 5–8

Kochaspis eiffelensis Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 226, pl. 14, fig. 4–10.

The impression of a large, articulated exoskeleton flattened in shale was collected at the type locality on Eiffel Peak, Alberta. Although very poor, this specimen shows that the thorax had 15 segments. The pleura, at least the posterior ones, terminate in sharp, backward-directed spines about one-third as long as the pygidial spines. The pleura are deeply furrowed throughout their length. The specimen preserves but a trace of the postero-lateral portion of the cranidium, showing the granular ornamentation characteristic of the species. The thorax has a length of 28 mm. and the pygidium of 5 mm.

A good cranidium and two good pygidia from Mt. Field are also figured.

Horizon and locality.—Type locality: W20d, Eiffel Peak, Alberta. Other figured specimens from locality W7ef. Mt. Field.

Types.—Holotype: U.S.N.M. 116125. Paratypes: U.S.N.M. 116126–8. Plesiotypes: G.S.C. 13548–50.

Genus KOCHIELLA Poulsen, 1927

KOCHIELLA? MAXEYI Rasetti

Pl. 120, fig. 1–3

Kochiella? maxeyi Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 228, pl. 13, fig. 5–8.

The only addition to the previous description of the species is the tentative assignment of a pygidium. Three specimens of this peculiar pygidium were collected from three different localities where the cranidia of the species are common. The main reason for the assignment is the identical character of the ornamentation.

Pygidium subrectangular as a whole, somewhat longer than wide. Axis occupying less than half the length and about two-thirds of the pygidial width, wider than long, rounded posteriorly, well defined laterally, but almost merging with the pleural lobes at the posterior end, especially in the larger individuals. Axis with an articulating furrow and two other shallow furrows, clearly marked, however, by the transverse rows of tubercles on the interposed rings. Pleural lobes sloping laterally but flat in longitudinal profile, with somewhat curved lateral outline, forming a posterior pair of rounded lobes separated by a shallow median notch. Three pairs of pleural furrows turn almost immediately backward to assume a longitudinal course and die out in the posterior, unfurrowed portion of the lobes. No border furrow or border. Surface of test very finely granulated; tubercles are arranged more or less regularly in four or five rows on the axial rings, and a few appear on the anterior portion of the pleural lobes. Length of largest pygidium 7 mm., width 6 mm.

A cranidium of the species is figured in order to show the identical ornamentation as observed on the pygidia.

Should the assignment of the two parts to one species be confirmed, this form should probably be assigned to a new genus.

Horizon and locality.—The two figured pygidia were collected from localities W7ef, Mt. Field, and W20d, Eiffel Peak. A third, incomplete specimen was found at locality W28f, Mt. Field.

Types.—Holotype: U.S.N.M. 116114. Figured plesiotypes: G.S.C. 13551–3.

KOCHIELLA? GIBBOSA Rasetti, n. sp.

Pl. 121, fig. 1–4

Known from numerous cranidia well preserved in limestone.

General shape similar to *Kochiella? maxeyi*, with the glabella proportionately longer, occupying with the occipital ring 65 per cent of the cranidial length instead of 60 per cent in *K. maxeyi*. Glabella moderately tapered, truncated in front, with slightly concave side outline. Four pairs of glabellar furrows impressed, forming the identical pattern as in *K. maxeyi*. Occipital ring short (sag.), bearing a small spine. Dorsal furrow deeper than in that species. Frontal area divided laterally into preglabellar field and border; a median boss in the preglabellar field renders the border furrow obsolete. Palpebral area slightly convex, on the average horizontal; palpebral lobes elevated, continuous with the strong ocular ridges, moderately wide, more than half as long as the glabella; width of palpebral area equal to glabellar width at the same level. Posterior area not extending laterally far beyond the palpebral lobes. Anterior facial sutures almost straight, slightly convergent. Posterior branch relatively straight; posterior area widely and deeply furrowed. Ornamentation consisting of fine granules among which are scattered granules of a larger size. Length of largest cranidium 5 mm.

This species differs from *K. maxeyi* in the relatively longer glabella, presence of a preglabellar boss, spinose occipital ring, larger palpebral lobes, and shorter (tr.) posterior area. It is questionable whether the two forms should be placed in the same genus, and whether either of them is congeneric with the type of *Kochiella*.

Horizon and locality.—The type is from locality W28fg. Mt. Field. Also occurring at localities W7e, W7f, and W28f, Mt. Field.

Types.—Holotype: G.S.C. 13554. Paratypes: G.S.C. 13555.

Genus ONCHOCEPHALITES Rasetti, n. gen.

Small trilobites similar to *Onchocephalus* or *Syspacephalus*. All cranidial furrows very shallow on external surface, excepting occipital and posterior border furrow which are well impressed. Glabella almost undefined anteriorly on outer surface; palpebral area about half the glabellar width; ocular ridges indistinct; palpebral lobes at level of glabellar midpoint, long and narrow; posterior area not extending laterally far beyond the palpebral lobes. Anterior facial suture first directed almost straight forward, turning inward sharply after crossing border furrow, meeting the rostral suture at a definite angle.

Type species.—*Onchocephalites laevis* Rasetti, n. sp.

Remarks.—The genus differs from *Syspacephalus* in the more posterior position and greater length of the palpebral lobes; from *Onchocephalus* in the obsolete condition of the furrows and the narrower palpebral area. It also differs from both genera in the more angular course of the anterior branch of the facial suture. Possibly in all generalized ptychopariids the suture undergoes some change in direction anterior to the border furrow, and almost certainly forms an angle where it meets the rostral suture; however, usually these angles are concealed in dorsal view, the anterior outline of the cranidium appearing smoothly rounded, instead of angular like in the present genus.

ONCHOCEPHALITES LAEVIS Rasetti, n. sp.
Pl. 121, fig. 5–9; text-fig. 2

Known from several well preserved cranidia.

Glabella defined posteriorly on outer surface, anteriorly almost merging with the preglabellar field, rounded in front, convex transversely, with two pairs of indistinct furrows. Occipital furrow almost obsolete in median portion but well impressed laterally; occipital ring rounded. Palpebral area definitely downsloping, of little convexity; palpebral lobe two-fifths as long as the glabella, very narrow, slightly elevated; frontal area downsloping, slightly convex; anterior border furrow obsolete in medial portion, shallow laterally. Posterior area with well-impressed furrow. Surface of test smooth. Length of largest cranidium 6.5 mm.

Horizon and locality.—W28fg, Mt. Field.

Types.—Holotype: G.S.C. 13556. Paratypes: G.S.C. 13557.

Genus ONCHOCEPHALUS Resser, 1937

ONCHOCEPHALUS MAIOR Rasetti
Pl. 120, fig. 11

Onchocephalus maior Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 234, pl. 14, fig. 19–23.

An excellently preserved cranidium is figured in order to show the ornamentation.

Horizon and locality.—The type locality is W7f, Mt. Field. The specimen figured herein

EXPLANATION OF PLATE 119

All figured specimens preserve the test unless otherwise indicated. Only one photograph of each stereogram pair is numbered.

FIG. *1,2—Oryctocephalites resseri* Rasetti, ×5. *1*, Cranidium, showing small, broken intergenal spines. *2*, Pygidium. Locality W7ef, Mt. Field; G.S.C. 13547, plesiotypes.

3,4—Loxopeltis problematica Rasetti, n. gen., n. sp. *3*, Large pygidium, ×3. Locality W7 (talus), Mt. Field; G.S.C. 13578, paratype, *4*, Smaller pygidium, ×5. Locality W28fg. Mt. Field; G.S.C. 13577, holotype.

5–8—Kochaspis eiffelensis Rasetti. *5*, Large pygidium, ×2. Locality W7ef, Mt. Field; G.S.C. 13549a. *6*, Small cranidium, ×5. Locality W7ef, Mt. Field; G.S.C. 13550. *7*, Small pygidium, ×5. Locality W28fg, Mt. Field; G.S.C., 13549b. *8*, Impression of adult individual showing thorax and pygidium, ×1.5. Locality W20d, Eiffel Peak; G.S.C. 13548. All specimens plesiotypes.

9–11—Plagiura cercops (Walcott). *9,10*, Immature cranidia, ×12. Locality W28f, Mt. Field; G.S.C. 13564, plesiotypes. *11*, Large exoskeleton poorly preserved in shale, ×1.5. Locality W20d, Eiffel Peak; G.S.C. 13565, plesiotype.

12–15—Dolichometopsis? sp. undet., ×5. *12*, Pygidium with wide pleural lobes. Locality W7c, Mt. Field; G.S.C. 13544d. *13*, Pygidium with wide pleural lobes. Locality W28f, Mt. Field; G.S.C. 13544c. *14*, Pygidium with narrow pleural lobes. Locality W28f, Mt. Field; G.S.C. 13542b. *15*, Pygidium with narrow pleural lobes. Locality W20d, Eiffel Peak; G.S.C. 13543. See also Plate 118.

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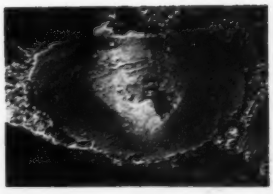

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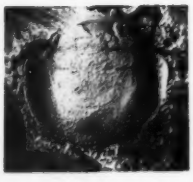

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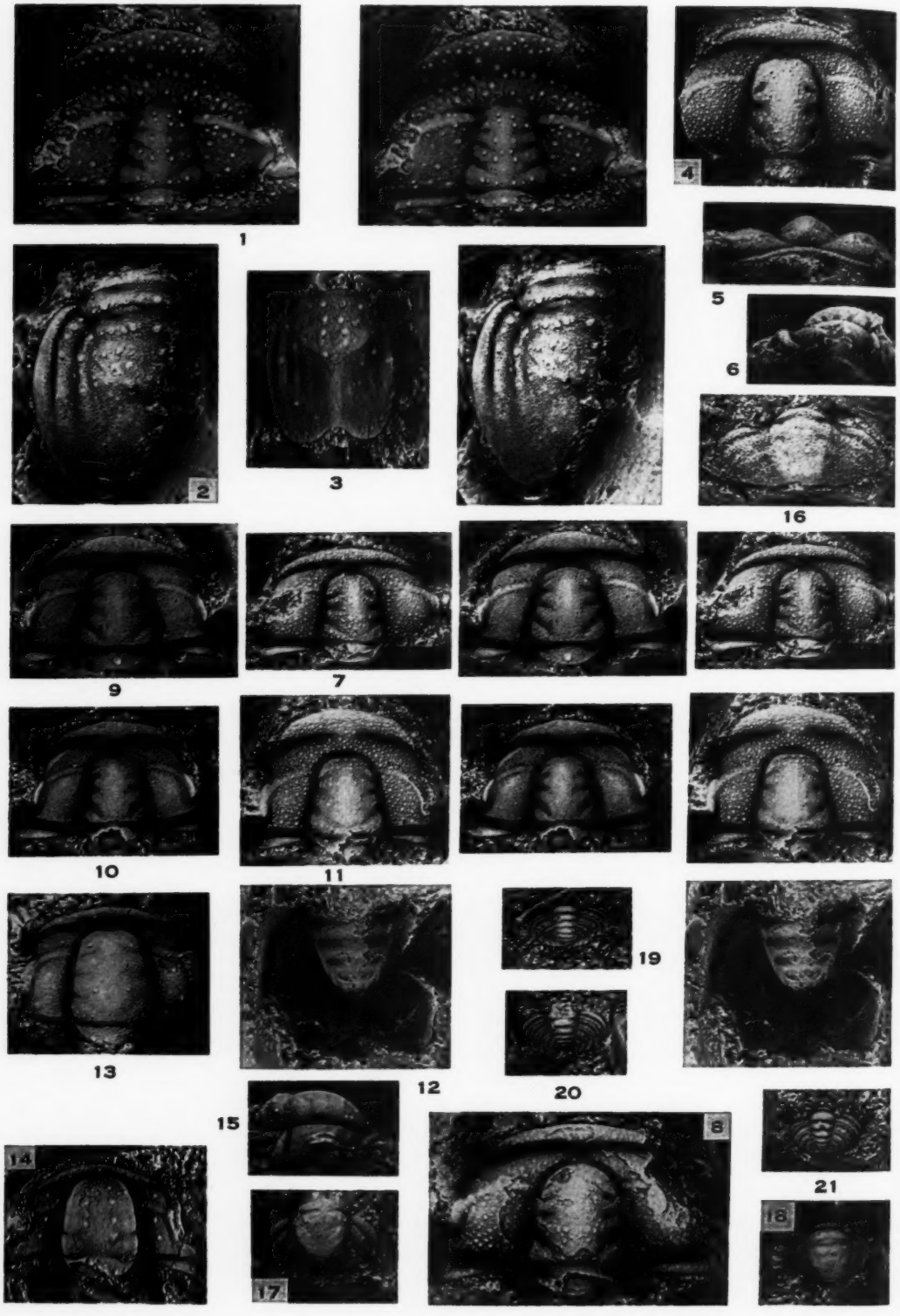
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is from locality W7ef, Mt. Field.

Types.—Holotype: U.S.N.M. 116134. Paratypes: U.S.N.M. 116135. Plesiotype: G.S.C. 13558.

ONCHOCEPHALUS SKAPTA (Walcott)
Pl. 120, fig. 9

Ptychoparia skapta Walcott, 1917, Smithsonian Misc. Coll., v. 67, no. 3, p. 95, pl. 12, fig. 9,9a.
Antagmus skapta (Walcott), Resser, 1937, Smithsonian Misc. Coll., v. 95, no. 22, p. 2.
Caborcella skapta (Walcott), Rasetti, 1951, Smithsonian Misc. Coll. v. 116, no. 5, p. 210, pl. 13, fig. 1–4.

The author's revision of several generalized ptychopariid genera (Rasetti, 1955) suggests the change in the generic reference of this species. The proportions of the cranidial parts are the same as those of several species referred to *Onchocephalus*. In this species, the furrows are deeper and consequently the relief more accentuated than in the type species and most of the others referred to the genus. However, there is such a continuous gradation in this respect that it seems difficult to place a generic boundary between these forms.

Horizon and locality.—The holotype is from U.S.N.M. locality 62w, *Plagiura-Kochaspis* zone, Mt. Assiniboine district, Alberta. The plesiotype figured herein is from locality W7ef, Mt. Field.

Types.—Holotype: U.S.N.M. 64392. Plesiotype: G.S.C. 13559.

ONCHOCEPHALUS cf. O. SKAPTA (Walcott)
Pl. 120, fig. 10

A single, perfectly preserved cranidium differs from the types in the proportionately slightly smaller glabella, longer (sag.) frontal area, and possibly slightly more convergent anterior facial sutures. From one specimen it is impossible to decide whether these differences are due to individual variation, or all the population at the locality shares these characteristics. The specimen is figured mainly because it is somewhat intermediate between *O. skapta* and other species referred to the genus, thus supporting the assignment of the species to *Onchocephalus*.

Horizon and locality.—W28fg. Mt. Field.

Figured specimen.—G.S.C. 13560.

Genus PARAPOULSENIA Rasetti, n. gen.

Small, generalized ptychopariid trilobites. Glabella prominent, slightly tapered, with three deep pairs of short furrows; occipital ring not spinose. Frontal area divided into a short (sag.) preglabellar field and a

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EXPLANATION OF PLATE 120

All figured specimens preserve the test unless otherwise indicated. Only one photograph of each stereogram pair is numbered.

FIG. *1–3*—*Kochiella? maxeyi* Rasetti. *1*, Small cranidium, ×5. Locality W7ef, Mt. Field; G.S.C. 13552. *2*, Pygidium tentatively attributed to the species, ×5. Locality W20d, Eiffel Peak; G.S.C. 13551. *3*, Smaller pygidium, ×8. Locality W7ef, Mt. Field; G.S.C. 13553. All specimens plesiotypes.

4–7—*Parapoulsenia lata* Rasetti, n. gen., n. sp., ×5. *4*, Cranidium. Locality W7ef; G.S.C. 13562, paratype. *5–7*, Frontal, lateral, and dorsal views of cranidium. Locality W7ef; G.S.C. 13561, holotype.

8—*Parapoulsenia* cf. *P. lata* Rasetti. Cranidium, ×5. Locality W28fg. Mt. Field; G.S.C. 13563.

9—*Onchocephalus skapta* (Walcott). Cranidium, ×5. Locality W7ef, Mt. Field; G.S.C. 13559, plesiotype.

10—*Onchocephalus* cf. *O. skapta* (Walcott). Cranidium, ×5. Locality W28fg. Mt. Field; G.S.C. 13560.

11—*Onchocephalus maior* Rasetti. Cranidium, ×5. Locality W7ef, Mt. Field; G.S.C. 13558, plesiotype.

12—Undetermined pygidium no. 1. Dorsal view, ×5. Locality W7f, Mt. Field; G.S.C. 13546.

13–15—*Schistometopus? minor* Rasetti, n. sp., ×5. *13*, Cranidium. Locality W7ef; C.S.G. 13571, paratype. *14,15*, Dorsal and lateral views of cranidium. Locality W7ef; G.S.C. 13570, holotype.

16—Undetermined pygidium no. 2. Dorsal view, ×12. Locality W7ef, Mt. Field; G.S.C. 13572.

17—Undetermined pygidium no. 3. Dorsal view, ×12. Locality W7ef, Mt. Field; G.S.C. 13573.

18—Undetermined pygidium no. 4. Dorsal view, ×12. Locality W7ef, Mt. Field; G.S.C. 13574.

19–21—Undetermined pygidium no. 5, ×12. *19*, Specimen from locality W28fg. Mt. Field. *20*, Specimen from locality W7ef, Mt. Field; G.S.C. 13575. *21*, Another specimen from the same locality, possibly belonging to a different species. G.S.C. 13576.

narrow (sag.), convex border, moderately arched transversely. Ocular ridges distinct; palpebral lobes small, somewhat elevated, slightly anterior to level of glabellar midpoint; palpebral area convex, on the average horizontal, as wide as the glabella. Anterior facial sutures convergent in dorsal view; posterior branch almost straight from eye to posterior border. Posterior area somewhat wider (tr.) than occipital ring, well furrowed. Surface granulated.

Type species.—*Parapoulsenia lata* Rasetti, n. sp.

Remarks.—The genus is erected for a species which partakes of the characters of many generalized ptychopariid genera but is distinctive chiefly in the great width of the palpebral area and the unusual depth of the three short pairs of glabellar furrows. Both characters separate it from *Poulsenia* which it otherwise resembles in the other features.

PARAPOULSENIA LATA Rasetti, n. sp.
Pl. 120, fig. 4–7; text-fig. 1

Known from numerous, well preserved cranidia.

Glabella tapered in the posterior half, parallel-sided in the anterior portion, hence with somewhat concave sides. First pair of glabellar furrows obsolete; second pair deep and short, directed inward and forward from the dorsal furrow; third pair equally deep and short, directed transversely; fourth pair longer, directed inward and backward, showing the usual tendency to bifurcate. Occipital furrow deep at the sides, shallower medially; occipital ring rather long (sag.), rounded, bearing a small node. Ocular ridges of average strength, starting transversely from the glabella and curving backward; palpebral lobes about one-fourth the glabellar length, fairly wide, set off by a distinct palpebral furrow. Anterior border furrow deep, with a slight median inbend; preglabellar field as long (sag.) as the border on midline, slightly depressed; border convex, decreasing in width at the sides. Posterior cranidial border showing distinct geniculation at one-fourth the distance from the distal end of the posterior area. Surface covered with fine granules and scattered granules of larger size. Length of largest cranidium 5 mm.

Horizon and locality.—W7ef, Mt. Field.

Types.—Holotype: G.S.C. 13561. Paratypes: G.S.C. 13562.

PARAPOULSENIA sp. cf. P. LATA Rasetti
Pl. 120, fig. 8

A few specimens, collected from higher beds than those yielding the type of the species, show several distinctive features but are not assigned to a separate species on account of the scarcity of the material.

The main differences from the type of *P. lata* are the proportionately broader, more uniformly tapered glabella, the less definite geniculation in the posterior cranidial margin, and possibly a greater convexity of the palpebral area.

Horizon and locality.—W28fg, Mt. Field.
Figured specimen.—G.S.C. 13563.

Genus PLAGIURA Resser, 1935
PLAGIURA CERCOPS (Walcott)
Pl. 119, fig. 9–11

Ptychoparia? cercops Walcott, 1917, Smithsonian Misc. Coll., v. 67, no. 3, p. 81, pl. 12, fig. 1, 1a–d.
Plagiura cercops (Walcott), Resser, 1935, Smithsonian Misc. Coll., v. 93, no. 5, p. 43.
Ptychoparia? cleadas Walcott, 1917, Smithsonian Misc. Coll., v. 67, no. 3, p. 83, pl. 12, fig. 2.
Plagiurella cleadas (Walcott), Resser, 1937, Smithsonian Misc. Coll., v. 95, no. 22, p. 23.
Plagiura cleadas (Walcott), Lochman, 1947, Journ. Paleontology, v. 21, p. 66.
Plagiura cercops (Walcott), Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 237, pl. 13, fig. 10–16.

An almost complete adult specimen was collected from locality W20d on Eiffel Peak, the only known locality where trilobites of the *Plagiura-Kochaspis* zone occur in shale and articulated exoskeletons are occasionally found.

The specimen shows a sufficient portion of the cranidium to identify the species, a thorax of 15 segments, and the pygidium. The length of the thorax is 31 mm. and that of the pygidium less than 4 mm.

Also figured are two immature cranidia from Mt. Field. The smaller, presumably belonging to a meraspid stage, is 1.3 mm. long. At this stage the glabella is very long, conical, unfurrowed, and reaches the border furrow. The eyes are even more anterior in position than in larger individuals. The other cranidium, 2.2 mm. long, matches in size and shape Walcott's type of *Ptycho-*

paria? cleadas. Shallow glabellar furrows are generally observable in cranidia of this size or a little larger, but disappear in the adult.

Horizon and locality.—The type locality is U.S.N.M. 63c, Ptarmigan Pass, Alberta. The specimens figured herein are from localities W20d, Eiffel Peak, Alberta, and W28f, Mt. Field.

Types.—Holotype: U.S.N.M. 64378. Plesiotypes figured herein: G.S.C. 13564–5.

Genus POULSENIA Resser, 1936
POULSENIA COLUMBIANA Rasetti, n. sp.
Pl. 121, fig. 10,11

Known from two well preserved cranidia. Glabella prominent, well defined by the dorsal furrow, not too sharply truncated in front, with the first pair of furrows barely visible, the other three short and shallow. Occipital furrow well impressed; occipital ring rounded, bearing a low node. Preglabellar field short (sag.), depressed medially, downsloping; anterior border arched transversely, somewhat expanded backward medially, narrowing laterally. Palpebral area four-fifths the glabellar width at midlength, convex, on the average slightly downsloping; palpebral lobes about one-third the glabellar length, at level of glabellar midpoint, moderately elevated; ocular ridges broad; posterior area well furrowed. Anterior branch of facial suture appearing convergent in dorsal view on account of the downsloping lateral portions of the frontal area. Surface covered with small granules, among which are scattered granules of larger size. Length of largest cranidium 6 mm.

This species closely resembles in all cranidial proportions the type species, *P. grönvalli* (Poulsen), differing only in minor details such as the broader ocular ridges and the more convex anterior border.

It should be pointed out that the present species also closely resembles *Solenopleura parva* Linnarsson whose type specimen was recently well illustrated by Westergård (1953). Actually, the latter species is more similar to *Poulsenia* than to the type of the genus, *S. canaliculata* (Angelin). In his revision of the genus *Solenopleura*, Westergård allowed a considerable degree of variation in a number of cranidial features, such as position of the eyes, width of the palpebral area, relative size of the glabella, etc. By the closely discriminative standards now used by American paleontologists in dealing with ptychopariids, *Solenopleura* should be split into at least 4 genera, one of which, exemplified by *S. parva*, might be included in *Poulsenia*. However, Westergård affirms that these different species are connected by intermediate forms which show their close relationship, and was probably well justified in leaving all in *Solenopleura*.

The question arises whether *Solenopleura* should be used for American species. As a reaction to the indiscriminate assignment of American Cambrian trilobites to unrelated European genera, certain authors went to the other extreme by denying *a priori* that any Cambrian trilobite from the Appalachian and Cordilleran provinces could belong to a genus from the Acado-Baltic province. This position does not seem justifiable, since cases are known of genera (e.g. *Peronopsis*, *Triplagnostus*, etc.) where forms from the Acado-Baltic and Cordilleran provinces are virtually indistinguishable. Hence, if an American trilobite appeared to agree in all characters with *Solenopleura canaliculata*, the writer would not hesitate to place it in that genus.

Horizon and locality.—W7ef, Mt. Field.

Types.—Holotype: G.S.C. 13566. Paratype: G.S.C. 13567.

Genus SCHISTOMETOPUS Resser, 1938
SCHISTOMETOPUS CONVEXUS Rasetti, 1951
Pl. 121, fig. 14–17

Schistometopus convexus Rasetti, 1951, Smithsonian Misc. Coll., v. 116, no. 5, p. 238, pl. 13, fig. 17–22.

This common species, one of the most useful diagnostic fossils of the *Plagiura-Kochaspis* zone in the Canadian Rockies, is discussed here because of the tentative assignment of a pygidium. Most of the specimens of this pygidium were collected from locality W7ef, where the cranidia of the species are particularly abundant.

The pygidium has a relatively short, prominent, posteriorly rounded axis with two or three very shallow furrows. The pleural lobes have well-rounded anterior angles, fairly straight lateral outline, and terminate into a pair of large, flat spines separated by an almost straight portion of

the posterior margin. Three pairs of shallow, backward-turning pleural furrows are visible; interpleural grooves entirely obsolete. The shape of the lateral outline, the length of the spines, and other features of the pleural lobes are subject to considerable variation, as shown by the photographs of three pygidia reproduced herein. These different forms intergrade in such manner that it is not possible to separate them into more than one species. The ornamentation consists of dense, extremely fine granulation and a few, low, regularly arranged tubercles on the axis; in some specimens there are also a few tubercles on the pleural lobes. The largest pygidium has a length on the midline of 2.9 mm. and width of 4.6 mm.

The association with the cranidia as well as the same type of ornamentation are the main reasons for the suggested assignment of the pygidium to the species. Another argument in favor is the similarity of the cranidium of *Schistometopus typicalis* to that of *Kochaspis eiffelensis*, which also posseses a spinose pygidium. The two cranidia essentially differ in the reduction of the preglabellar field in the former species.

A possibility that should be kept in mind, although the writer considers it less probable, is that the pygidia here assigned to *Kochiella? maxeyi* and *Schistometopus convexus* should be interchanged. The observed associations would be equally consistent with this alternative assumption, but the ornamentation suggests the present reference as more satisfactory.

It is remarkable that the same problem is presented by the association of pygidium and cranidium described by Walcott as *Crepicephalus chares*, from locality U.S.N.M. 63d at Ptarmigan Pass, Alberta. The writer (1951, p. 228) previously expressed the opinion that Walcott's pygidium of that species belongs to a species of *Fieldaspis*. Although it now seems more probable that it belongs with a ptychopariid cranidium, there are still two possible choices. On the same piece of rock with the cranidia of *Crepicephalus chares* (which is almost identical with *Kochiella? maxeyi*) are two large cranidia of a *Schistometopus* (which Walcott did not describe) similar to *S. convexus* or *S. collaris*. The pygidia are very similar to the one here assigned to *Schistometopus convexus*. If this assignment is correct, then it is more likely that Walcott's pygidia belong with the *Schistometopus* head. On the other hand, if the assignments of the *Schistometopus convexus* and *Kochiella? maxeyi* pygidia should be inverted, then Walcott's pygidium would likely belong to the *Crepicephalus chares* cranidium according to his original reference. This puzzle can only be solved by the discovery of articulated specimens.

Horizon and locality.—The holotype is from locality W20d, Eiffel Peak, Alberta. The specimens figured herein are from locality W7ef, Mt. Field.

Types.—Holotype: U.S.N.M. 116120. Paratypes: U.S. N.M. 116121-2. Plesiotypes: G.S.C. 13568-9.

SCHISTOMETOPUS? MINOR Rasetti, n. sp.
Pl. 120, fig. 13–15

Known from several, well preserved cranidia.

Glabella but slightly tapered, with slightly convex sides, fairly rounded in front, usually showing a faint median indentation, rising well above the fixed cheeks. Three pairs of very shallow glabellar furrows, those of posterior pair curving backward; occipital furrow well impressed throughout: occipital ring rounded. Palpebra area one-half the glabellar width, almost flat, slightly downsloping; ocular ridges present; palpebral lobes one-third the glabellar length, rather narrow, not greatly elevated, set off by a distinct palpebral furrow. Frontal area moderately downsloping; preglabellar field absent medially on account of the confluence of the dorsal and border furrows; border well defined, moderately convex, widest (sag.) on midline, flat transversely. Posterior area about as wide (tr.) as the occipital ring; posterior branch of facial suture first directed outward, then sharply curving backward to posterior margin; distance from posterior end of palpebral lobe to posterior margin equal to length of palpebral lobe. Anterior branch of facial suture relatively short, directed slightly inward, straight to anterior margin. Surface very finely granulated; in addition, there are several pairs of tubercles symmetrically arranged on glabella and fixed cheeks. Length of largest cranidium 3.5 mm.

The species is referred to *Schistometopus*

with a question mark. Compared with *S. convexus*, the glabella has a more ovate shape, the ocular ridges have a different course, and the palpebral area and palpebral lobes are less elevated. The main feature that suggested tentative reference to the genus is the absence of a preglabellar field.

Horizon and locality.—W7ef, Mt. Field. One cranidium that may be referred to the species was collected from locality W28fg, Mt. Field.

Types.—Holotype: G.S.C. 13570. Paratypes: G.S.C. 13571.

Undetermined pygidium no. 2
Pl. 120, fig. 16

Pygidium two and one-half times wider than long, of the simple type common to primitive ptychopariids. Axis occupying less than one-third of the width, elevated, reaching the posterior margin, showing two faint furrows in addition to the articulating furrow. Pleural lobes downsloping, with one marked furrow and traces of two more pairs. Border furrow and border indistinct. Surface finely and densely granulated. Length of largest specimen 1.6 mm., width 4.0 mm.

Plausible candidates for this ptychopariid pygidium, suggested by association, are *Onchocephalus maior* and *Parapoulsenia lata*.

Horizon and locality.—Three specimens of this pygidium were collected from the beds W7ef, Mt. Field.

Figured specimen.—G.S.C. 13572.

Undetermined pygidium no. 3
Pl. 120, fig. 17

Pygidium somewhat less than twice wider than long. Axis prominent, almost reaching the posterior margin, about as wide as long, showing a faint furrow in addition to the articulating furrow. Pleural lobes downsloping, with three pairs of distinct, backward-curved furrows and traces of interpleural grooves. Furrows almost reaching the margin; border furrow and border indistinct. The posterior margin has a shallow median notch. Surface granulated. Length of pygidium 0.85 mm., width 1.5 mm.

This pygidium may belong to one of the ptychopariid cranidia known from the same beds, possibly *Onchocephalus skapta*.

Horizon and locality.—One specimen was collected from the beds W7ef, Mt. Field.

Figured specimen.—G.S.C. 13573.

Undetermined pygidium no. 4
Pl. 120, fig. 18

Pygidium very small, one and one-half times wider than long, suboval in outline. Axis very wide, prominent but not well defined from the pleural lobes, tapered, reaching the posterior margin, with two very shallow furrows. Pleural lobes narrow, downsloping, unfurrowed; border indistinct. Surface apparently smooth. Length of specimen 0.75 mm., width 1.1 mm.

Horizon and locality.—W28fg, Mt. Field.

Figured specimen.—G.S.C. 13574.

Undetermined pygidium no. 5
Pl. 120, fig. 19–21

Pygidium very small, twice wider than long. Axis narrow, prominent, tapered, with 6 distinct rings, reaching the posterior margin. Pleural lobes flat; anterior angles well rounded; posterior margin with a slight median notch at least in some of the specimens. Pleural furrows very distinct, curving backward, extending to the margin; interpleural grooves shallower and narrower but also distinct; pleura, at least in the first two or three segments, extended into short marginal spines. Surface very finely granulated. Length of typical pygidium 0.66 mm., width 1.1 mm.

The incomplete fusion of the anterior pleural segments and the small size suggest that this is a transitory pygidium, possibly belonging either to *Schistometopus convexus* or *Kochaspis eiffelensis*. There may be more than one species represented among the pygidia of this type.

Horizon and locality.—W7ef and W28fg, Mt. Field.

Figured specimens.—G.S.C. 13575–6.

Superfamily and family undetermined
Genus LOXOPELTIS Rasetti, n. gen.

Known from the pygidium alone. Pygidium approximately in form of a circular arc, with straight, very oblique anterior outline and regularly curved posterior margin. Axis prominent, about four-fifths the pygidial length, tapered, with three pairs of furrows more deeply impressed at the sides. Pleural lobes slightly downsloping, with faint,

straight pleural furrows and poorly defined border.

Type species.—*Loxopeltis problematica* Rasetti, n. sp.

Remarks.—There is no known pygidium of similar shape among trilobites of comparable age, hence it is impossible to guess the type of cranidium associated with it and its systematic position. The unusually oblique anterior outline of the pleural lobes indicates a trilobite where the pleura of the posterior segments of the thorax formed an angle of about 45° with the axis of the body. Although the writer considers it generally improper to erect trilobite genera on pygidia, for the reason that this procedure often leads to duplication with genera based on cranidia, an exception is made in the present case since it seems virtually certain that this pygidium cannot belong to any described genus.

LOXOPELTIS PROBLEMATICA Rasetti, n. sp.
Pl. 119, fig. 3,4; text-fig. 4

There is little to be added to the generic diagnosis. Pygidial axis showing three furrows in addition to the articulating furrow, and a trace of a fourth. None of the furrows reach the dorsal furrow. Those of the first two pairs end in deeper depressions located very close to but not merging with the dorsal furrow. The axis is extended into a slight elevation that reaches the posterior margin. The pleural lobes are anteriorly truncated at about 45° and a well pronounced facet extends through the straight anterior outline. About 4 pairs of very shallow furrows, possibly to be interpreted as alternating pleural furrows and interpleural grooves, fan out and end in somewhat deeper depressions in the shallow border furrow. The border is slightly convex and poorly defined. Surface of test smooth. Length of largest pygidium 9.5 mm., width 10.5 mm.

Horizon and locality.—Of the three known specimens (of which only two well preserved), the holotype was collected at locality W28fg, Mt. Field. The other two were found in loose blocks at the foot of the cliff (locality W7) and hence the precise horizon is unknown.

Types.—Holotype: G.S.C. 13577. Paratypes: G.S.C. 13578.

GASTROPODA

The Cambrian gastropods and gastropod-like forms have not been objects of adequate study. Such organisms were usually described incidentally as a relatively minor component of Cambrian faunas. Knight (1952) has given an excellent account of the problems presented by the phylogeny and classification of primitive gastropods.

As Knight points out, almost nothing is known of the muscle scars and other internal structures which might give an indication of the anatomy, most of the Cambrian gastropods exhibiting only the appearance of the external surface. Some progress in this direction was made by the author (Rasetti, 1954) who described well preserved, bilaterally symmetric muscle scars in a conical shell common in the Mt. Whyte formation and referred to *Scenella*, although there is no satisfactory evidence that it is related to the type of that genus. This organism appears to be the earliest well-authenticated member of the monoplacophoran gastropods.

Coiled gastropods are also relatively common in most of the Lower and Middle Cambrian formations of North America, and in particular in the Mt. Whyte formation. Two species, represented by well-preserved individuals, were studied both externally and by means of sections. The latter procedure revealed interesting structures to be described presently.

Shells of this type were referred by Resser (1938) to the genus *Helcionella*, tentatively considered by Knight a monoplacophoran. However, Knight did neither place in *Helcionella* nor consider as Monoplacophora most of the species that Resser included in *Helcionella*. Two such forms figured by Knight (1952, pl. 1, fig. 5,6) are instead referred to *Oelandia*, assigned to the family Coreospiridae and believed to be a primitive bellerophont. Thus *Helcionella* as construed by Resser would be a mixture of forms across the dividing line between the Isopleura and the Anisopleura. However, Knight himself (1952, p. 24–33) is uncertain about the position of this line, as evidenced by his statement (1952, p. 29):

> I have placed the dividing line between *Helcionella* and *Oelandia*, placing the former in the Isopleura with the Monoplacophora and the

latter in the Anisopleura with the bellerophonts. If anyone prefers to class the Coreospiridae with the Monoplacophora or *Helcionella* with the bellerophonts, I cannot quarrel too vigorously with the preference. There is insufficient evidence.

Mainly on the basis of undescribed material from the Lower and Middle Cambrian of Quebec, the author inclines toward the view that the dividing line between the Monoplacophora and the bellerophonts cannot be placed according to Knight's suggestion, i.e. between *Helcionella* and *"Oelandia"* (quotation marks indicate that the name is used not for the type of the genus, but for the North American species referred to it by Knight). There is an almost unbroken series of intermediate forms between the type of *Helcionella* (Knight, 1952, pl. 1, fig. 2a,b) and species which he placed in "Oelandia" (fig. 5,6). Even an obviously conspecific population for a single piece of rock may show partly the characters of *Helcionella* and partly those that Knight attributed to *"Oelandia."*

If one accepts this conclusion, then species of *Helcionella* and *"Oelandia"* are either all Monoplacophora or all primitive bellerophonts. The latter conjecture may be the more likely, since the *"Oelandia"*-like forms intergrade with closely coiled shells of the *Coreospira* type, and it seems less plausible to attribute the latter to the Monoplacophora.

On the other hand, the author knows no continuous series of forms between the *"Scenella"* possessing paired muscle scars (Rasetti, 1954), which seems an unquestionable monoplacophoran, and the type species of *Helcionella*. The most likely position of the dividing line seems to lie between these two. Whether the type of *Scenella, S. reticulata* Billings from the Lower Cambrian of eastern Newfoundland, belongs to the one or the other side cannot be decided at present.

The systematic position of the two gastropods to be described herein is now discussed in the light of the preceding remarks. The general shape of the shell is similar to *Oelandia* and to the American species referred to that genus by Knight and to *Helcionella* by Resser. However, the type of *Oelandia, O. pauciplicata* Westergård from the Middle Cambrian of Sweden, differs from all known American forms in the lack of complete bilateral symmetry of the shell. The coarse ridges on one side correspond to the alternating furrows on the opposite side, while all similar structures in American species are perfectly symmetrical. This may or may not be of fundamental significance; in the doubt, it seems best not to refer any symmetrical shell to *Oelandia*.

Hence the species described herein are referred (with a question mark) to *Helcionella*, construing the genus in the wide sense used by Resser. The writer is convinced that all these forms are closely related, since an almost unbroken series of intermediate species can be produced. Nevertheless, it may be objected that *Helcionella* now includes too great a variety of forms and should be split into three or four genera. It would be premature to attempt this subdivision until all known North American Lower and Middle Cambrian gastropods can be studied and the new species in hand are described. Awaiting the opportunity to accomplish this task, the author refrains from proposing new genera on the basis of an incomplete study.

Genus HELCIONELLA Grabau and Shimer, 1909

HELCIONELLA? INSULCATA Rasetti, n. sp.

Pl. 122, fig. 9–14

Known from numerous shells of various sizes, all showing the external surface.

Shell bilaterally symmetrical, cyrtiform, expanding rapidly, of not more than one whorl even in the larger individuals. Apertural margin almost in a plane, excepting posteriorly (the concave side of the whorl is arbitrarily considered posterior) where the margin is somewhat elevated; this feature is also clearly shown by the upward curvature of the growth lines. Anterior lip without an emargination; growth lines straight on outer surface of whorl. In cross section, the outer outline of the whorl is well rounded; the sides almost flat; the inner outline in form of a moderately sharp keel, on account of a pair of broad, shallow depressions on either side of the midline. These depressions vary in depth from one individual to another and are more accentuated toward the aperture in the larger shells; they are hardly marked in the smaller shells.

The ornamentation consists essentially of fine growth lines. However, some individuals (including the holotype) also display a trace of undulations, better visible on the flat sides of the whorl. This feature indicates that there is no fundamental difference between this almost smooth shell and the more common forms of *Helcionella* with prominent undulations; in fact, almost all possible intermediate stages are known. Longitudinal lines are totally absent in this species.

Length of the largest shell 13 mm., maximum width 5 mm.

Several of the larger shells (of which, unfortunately, few specimens were available) were sectioned parallel to or in the median plane. All those in which the apical portion of the shell was well preserved showed at least one septum, and in at least one individual, evidence for two septa was obtained. The septa are always slightly concave toward the aperture, and are usually unbroken by an opening. A septum is clearly visible in each of the two individuals represented by photographs of thin, sagittal sections in pl. 122, fig. 12,14. It will be noticed that, although the two shells are of about equal size, the septum in the specimen of fig. 12 is much closer to the apex than in the one shown in fig. 14. However, at a certain stage of the grinding of one side of the latter individual, two septa were distinctly observed (fig. 13 shows the polished surface at this stage); the inner one has about the same position as the only septum in the specimen of fig. 12. As the median plane was reached, this inner septum disappeared and only the outer one, showing in the thin section (fig. 14), remained visible. Possibly the coarse matrix filling the apical portion of this shell is responsible for the lack of complete preservation of the inner septum. Indication for two septa was found at some stage in the polishing of sections of other specimens, but not as clearly as in the case reported above.

The existence of septa in Cambrian gastropods had been pointed out to the author by Dr. T. Kobayashi; however, apparently there is no published information on the subject. Dr. J. Brookes Knight showed the writer a specimen of *Helcionella callahani* Resser from the Lower Cambrian of Virginia, where the apical portion of the shell was broken off along a smooth, slightly convex surface that evidently represents a septum. Some evidence for the presence of a septum was found in the other species described herein. It is thus possible that septa are a general feature of these primitive gastropods, and whenever possible specimens should be investigated by sectioning. Unfortunately most of these shells are too small to show such features except under ideal conditions of preservation, and often the delicate apical portion is broken off.

This species seems closely related to *Helcionella aequa* Resser from the Middle Cambrian (*Ptarmigania* strata) of Idaho. In that species, however, the cross section of the whorl is flatter on the outside and bounded by a pair of rounded ridges, thus approaching in shape the next species to be

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EXPLANATION OF PLATE 121

All figured specimens preserve the test unless otherwise indicated. Only one photograph of each stereogram pair is numbered.

FIG. *1–4—Kochiella? gibbosa* Rasetti, n. sp., ×5. *1,2*, Dorsal and frontal views of cranidium; G.S.C. 13554, holotype, *3,4*, Cranidia; G.S.C. 13555, paratypes. Locality W28fg, Mt. Field.

5–9—Onchocephalites laevis Rasetti, n. gen., n. sp., ×5. *5–7*, Dorsal, lateral, and frontal views of cranidium; G.S.C. 13556, holotype. *8*, Partly exfoliated cranidium showing furrows on internal surface. *9*, Larger cranidium. G.S.C. 13557, paratypes. Locality W28fg, Mt. Field.

10–11—Poulsenia columbiana Rasetti, n. sp., ×5. *10*, Cranidium; G.S.C. 13567, paratype. *11*, Cranidium; G.S.C. 13566, holotype. Locality W7ef, Mt. Field.

12,13—Fieldaspis bilobata Rasetti. *12*, Complete exoskeleton flattened in shale, ×2. Locality W20d, Eiffel Peak; G.S.C. 13536, plesiotype. *13*, Small pygidium, ×8. Locality W7ef, Mt. Field; G.S.C. 13537, plesiotype.

14–17—Schistometopus convexus Rasetti. *14*, Cranidium, ×3; G.S.C. 13568, plesiotype. *15–17*, Pygidia tentatively attributed to the species, ×8; G.S.C. 13569, plesiotypes. Locality W7ef, Mt. Field.

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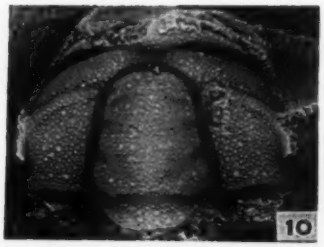

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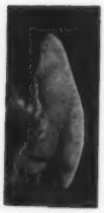

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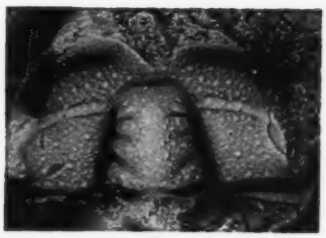

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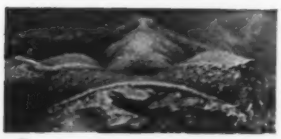

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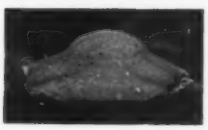

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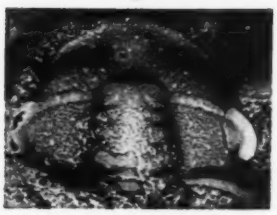

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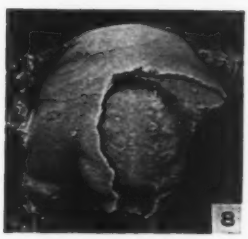

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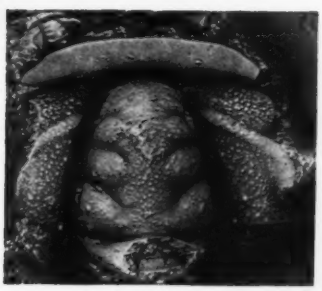

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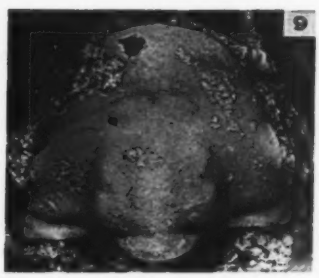

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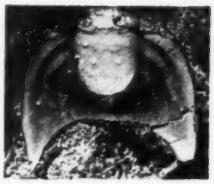

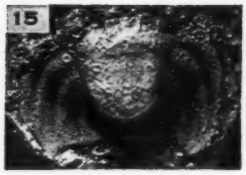

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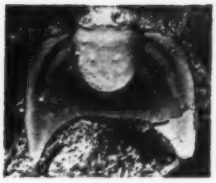

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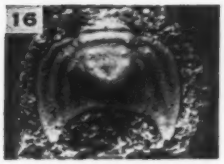

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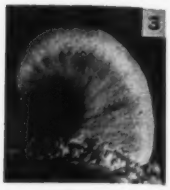
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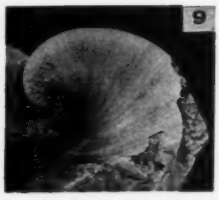
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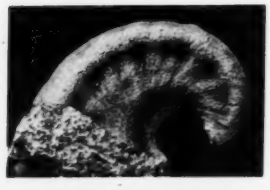

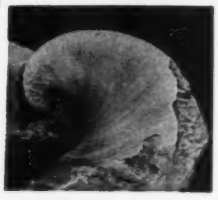

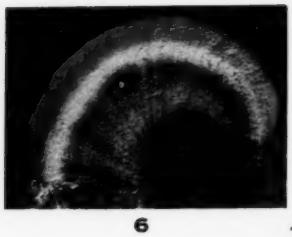
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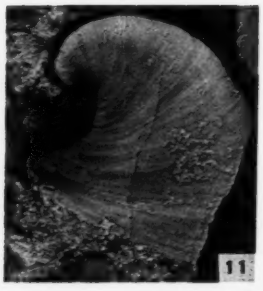
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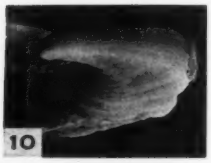
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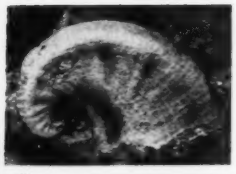
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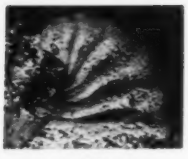
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described. More definite undulations are present on the lateral surface.

Horizon and locality.—The types are from locality W28fg, Mt. Field, where the species is relatively rare. Also found rarely at localities W7f and W28f, Mt. Field. An excellent example in the U. S. National Museum was collected by Walcott from locality U.S.N.M. 62w, in the *Plagiura-Kochaspis* zone near Gog Lake, Mt. Assiniboine district, Alberta.

Types.—Holotype: G.S.C. 13579. Paratypes: G.S.C. 13580–1.

HELCIONELLA? CARINATA Rasetti, n. sp.
Pl. 122, fig. 3–8

Known from numerous shells of different sizes, all showing the external surface.

Shell bilaterally symmetrical, cyrtiform, less rapidly expanding than in the preceding species, of not more than one whorl even in the larger individuals. Apertural margin almost in a plane, as evidenced by the growth lines, without any anterior emargination; growth lines oblique to the radius and tangent to the coil. Outer whorl surface flatly arched, bounded by a pair of rounded ridges that constitute the widest portion of the shell; sides definitely concave; umbilical shoulders relatively sharp; between these and the median plane is a pair of well-marked depressions, setting off a rounded ridge that forms the inner portion of whorl. The lateral ridges, the concave lateral surface, and the last-mentioned depressions and ridge are progressively more marked from the apex toward the aperture. In agreement with this fact, all these features are much less pronounced in the smaller shells.

The ornamentation consists of fine growth lines, faint longitudinal lines, clearly visible in some individuals but almost obsolete in others, and coarse undulations on the lateral surfaces, deepest in the portion adjacent to the lateral ridges. All the described features are subject to considerable variability, as evidenced by the 4 individuals figured. There are intergrading forms among a population from a single stratum, hence this variation is undoubtedly intraspecific.

Length of the largest shell 7.2 mm., maximum width at the aperture 3 mm.

A few of the larger shells were sectioned, and one showed a fairly clear septum analogous to those observed in *H. insulcata;* in the other specimens either the apical part was not well preserved, or even if it was, the septum could not be observed, as is the case for the specimen figured in pl. 122, fig. 4.

This species seems closely related to *H. aequa*, which, as mentioned before, is somewhat intermediate between *H. insulcata* and *H. carinata.*

It should also be mentioned that the present species has many features in common with *Coreospira walcotti* Knight (1947), also from the *Plagiura-Kochaspis* zone of the Mt. Whyte formation and hence at least approximately contemporaneous. The cross section of the whorl and ornamentation are similar, as far as specimens preserving the shell can be compared with internal casts. However, Knight described this gastropod as closely coiled, like the type species of

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EXPLANATION OF PLATE 122

All specimens shown in exterior view preserve the shell unless otherwise indicated. Only one photograph of each stereogram pair is numbered.

FIG. *1–2—Stenothecoides* cf. *S. elongata* (Walcott), ×5. *1,* Cast of internal surface of shell showing furrows. Locality W28fg, Mt. Field. *2,* Dorsal view of specimen preserving shell. Locality W28fg, Mt. Field. G.S.C. 13586a–b.

3–8—Helcionella? carinata Rasetti, n. sp., ×5. *3,5,8,* Lateral view of three specimens; G.S.C. 13583 a–c, paratypes. *4,* Thin sagittal section of shell; G.S.C. 13584, paratype. *6,7,* Lateral and oblique views of largest shell; G.S.C. 13582, holotype. Locality W7ef, Mt. Field.

9–14—Helcionella? insulcata Rasetti, n. sp. *9,10,* Lateral and oblique views of shell, ×3; G.S.C. 13579, holotype. *11,* Lateral view of largest specimen, ×3; G.S.C. 13580, paratype. *12,* Thin sagittal section of shell, showing septum, ×10. *13,* Polished section of shell parallel to but not in sagittal plane, showing two septa, ×10. *14,* Thin sagittal section of same specimen, showing only the outer septum; note different type of matrix filling the apical portion of the shell enclosed by the septum. G.S.C. 13581a–b, paratypes. Locality W28fg, Mt. Field.

15—Helcionella? sp. undet. Lateral view of shell, ×7.5. Locality W7f, Mt. Field; G.S.C. 13585.

Coreospira, and study of the type specimens seems to support this contention. The present species, which is not closely coiled, could not be referred to that genus. Hence it seems more proper to describe it as new and refer it to *Helcionella*.

Horizon and locality.—The types are from locality W7ef, Mt. Field. The species also occurs rarely at locality W28fg.

Types.—Holotype: G.S.C. 13582. Paratypes: G.S.C. 13583–4.

HELCIONELLA? sp. undet.
Pl. 122, fig. 15

A single individual represents in the Mt. Whyte formation the type of *Helcionella* most common in Middle Cambrian formations. The shell is less coiled than in the two preceding species and has pronounced, coarse undulations which extend all around the whorl. It seems futile to attempt specific assignment from one specimen.

Horizon and locality.—W7f, Mt. Field.

Figured specimen.—G.S.C. 13585.

Phylum undetermined
Genus STENOTHECOIDES Resser, 1938
STENOTHECOIDES cf. S. ELONGATA
(Walcott)
Pl. 122, fig. 1,2

Stenothecoides cf. *S. elongata* (Walcott), Rasetti, 1954, Jour. Paleontology, v. 28, p. 63, pl. 11, fig. 6–10; pl. 12, fig. 1–4.

In view of the previous discovery of structures on an internal cast of this shell, hundreds of specimens of this common fossil were collected and carefully examined. Unfortunately, only one individual was found to exhibit the cast of the internal surface. It shows the same general type of irregular furrows and ridges observed on the previous specimen, unfortunately somewhat marred by the coarseness of the matrix which obscures the finer details. Both the shell outline and the furrow pattern exhibit perfect bilateral symmetry, confirming the author's previous opinion that, notwithstanding the irregular shape of some of the shells, we are dealing with a bilaterally symmetric organism and there are no left or right valves. In the new specimen the furrows are not confined to the lateral slopes of the shell, but in part extend almost to the midline. Owing to the great irregularity and variation in shape among shells of this species, it is not surprising that the furrow pattern should present such differences. A more detailed description seems unnecessary, since the reproduced stereogram shows all the visible features of the specimen. A shell showing the outer surface is illustrated for comparison.

Horizon and locality.—The specimen showing the cast of the interior was collected from the beds W28fg, Mt. Field.

Figured specimens.—G.S.C. 13586.

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THE GEOLOGICAL SOCIETY OF AMERICA
PROJECT GRANT 668–55
MANUSCRIPT RECEIVED FEBRUARY 10, 1957

JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 973, SEPTEMBER 1957

PALEONTOLOGICAL NOTES

PRELIMINARY ANNOUNCEMENT OF AN IMPORTANT NEW FOSSIL DEPOSIT

JAMES D. BUMP AND HAROLD J. COOK
Rapid City, South Dakota and Agate, Nebraska

A student from the South Dakota School of Mines and Technology, while working on an REA project along the canyons forming the Niobrara River drainage in western Nebraska, discovered an important deposit which promises additional evidence on the climate and physical conditions in that region during Pliocene times. This newly discovered deposit more or less centers around the Loren Drinkwater ranch south of the town of Kilgore. Preliminary field examinations and collecting by the authors disclosed the character of the deposit and the extensive, finely preserved flora and fauna it contains. The fauna includes numerous fossil fish.

Dr. H. D. MacGinitie, Humboldt State College, agreed to help collect and classify the fossil plants and to study their ecology. He is now at work on a collection made in June, 1955, when he and the authors visited the site.

Although little collecting could be done at the locality this past year, plans are made to continue the field work in 1957, and to map the exposed limits of the deposit. Other specialists have agreed to participate, each in his own field, in a collaborative effort to learn as much as possible about this deposit. The present paper is primarily to announce this discovery and plans for continued research.

THEROPOD SAURISCHIAN FOOTPRINT DISCOVERY IN THE WINGATE (TRIASSIC) FORMATION

CARL M. BUNKER
U. S. Geological Survey, Denver 2, Colo.

C. M. Bunker and H. K. Martin have discovered fossil footprints approximately 40 feet above the base of the Wingate (Triassic) formation near the mouth of La Sal Creek on the Dolores River in Montrose County, Colorado. The Wingate is about 350 feet thick at that location. The tracks are in one of several thin mudstone seams which occur in the lower part of the section. The tracks are imbedded in a ripple-marked, mud-cracked surface. G. E. Lewis identifies the footprints as follows: "The footprints seem to be those of theropod saurischian 'dinosaurs' of the Infraorder Coelurosauria. Except for a noticeably shorter length of pace, they resemble those called *Grallator* by E. Hitchcock (described at length by R. S. Lull, 1953) from the Meriden and Portland series of the Newark group in Connecticut and Massachusetts. . . . I *guess* the age to be not older than Keuper on this footprint evidence."

JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 974–976, PL. 123, SEPTEMBER 1957

COLOR RETENTION IN *STENOPOCERAS*, *EUOMPHALUS*, AND *NATICOPSIS* FROM THE LOWER PERMIAN OF NORTH CENTRAL TEXAS

AUGUSTA HASSLOCK KEMP
Seymour, Texas

ABSTRACT—A single nautiloid, *Stenopoceras*, shows groups of growth lines alternately darker and lighter red brown. A quite similar coloration pattern was found on a *Nautilus pompilius* shell, one of eight examined.

Several horizons from the upper formations of the Lower Permian have yielded euomphalids retaining color. The best are from the Elm Creek of the Admiral formation. The pigment is diffused through the outer shell layer of the last two or three volutions. It is nearly black on the carinae and outer whorl face of the axial face and brownish on the basal.

Color-marked naticopsids were found in the Elm Creek and in a small outcrop, approximately Maybelle. In the former the shells are solid dark gray, or gray or tan with growth lines in a darker shade. In the latter small, matrix-protected shells, tan or light brown in color, have dark brown transverse bands lying on the very surface of the shell of the last volution.

SHELLS RETAINING COLOR

Stenopoceras.—This genus is represented by only one specimen, from the Maybelle limestones of the Lueders formation in the southwestern part of Baylor County, found by Bob Hayley, a lad of twelve. This specimen (pl. 123, fig. 9) shows a considerable portion of a lateral surface, probably from the shell of the body chamber. It is practically flat, though the lateral areas of a *Stenopoceras* are usually convex. The shell impression is only a thin film, reminding one of a fossil leaf. What seems to be the ventrolateral edge is distinct for 70 mm. and fairly so for 65 mm. more. A comparison of this ventral curve with that of a paratype of *Stenopoceras whitei* (the original of fig. 2, pl. 5, Miller & Youngquist, 1949), suggests the two fossils were about the same size and probably the same species. The sinuous growth lines are exceptionally well preserved, and, as stated by Miller & Youngquist (p. 70, 1949) in their generic description of *Stenopoceras*, "curve strongly apicad as they approach the ventral zone." It is these growth lines which make this specimen unique, for some of them are darker shades of light brownish red and some are lighter. The weathered surfaces along cracks in the light gray limestone matrix show this same color, but in a uniform tint.

The coloring of these growth lines in no way resembles the splotches usually found on the outer shell of *Nautilus pompilius.* However, the writer found, on examining the eight *Nautilus* shells available to her, one shell in which small groups of growth lines tinted cream alternate with groups colored pale pinkish tan. Though somewhat masked by the usual red brown splotches over the phragmocone area, this coloring extends from the dark portion of the involution of the shell to the apertural margin. The shell looks old but is nearly perfect, and this unique distribution of color, especially that over an area usually white, can hardly be ascribed to weathering.

Whereas descriptions of brevicones and longicones which retain color markings are unexpectedly abundant, the writer has found only one for a coiled cephalopod, an ammonite mentioned by Schindewolf (1931) in a brief note: "color streaks in Amaltheus —a new example with a spiral color band running parallel to the marginal edge" (translation). A 1928 reference to the same fossil was unobtainable.

Euomphalus.—Of the Lower Permian euomphalids collected by the writer, one is from the Maybelle limestones of the Lueders formation; two from the Talpa and three from the Grape Creek of the Clyde formation; and thirteen from the Elm Creek lime-

stones of the Admiral formation. All show pigmentation except two from the Clyde. All came from Baylor County, except one from the Grape Creek, seven miles west of Throckmorton, in Throckmorton County, which is directly south of Baylor.

The best specimens (pl. 123, fig. 1–5) are from the Elm Creek limestones and these have been identified as *Straparollus* (*Euomphalus*) *cornudanus* Shumard by Mr. Ellis P. Yochelson, U.S.G.S., who is currently studying the naticopsids discussed below.

The Elm Creek limestones are the uppermost members of the Admiral formation and outcrop, with interbedded clays and sandstone lenses or stream fillings, in a wide dip slope just east of Godwin Creek, along the eastern edge of Baylor County. They extend, below a north-south line of hills developed in the sandstones and calcareous nodular clays of the overlying Belle Plains formation, eastward into Archer County.

All but one of the Elm Creek euomphalids came from outcrops just south and east of Godwin Creek and a half mile or so south of the Archer City Road. Three show both sides, six the axial side, and four the basal. The apertural ends are incomplete and the central whorls indistinct. The shell diameters range from 20–57 mm., the average being 41 mm. These are larger than most of the colored euomphalids described by Knight (1934), the chief exception being his *S.* (*E.*) *plummeri*, the diameter of which is 55 mm.

The main mass of the shells is light colored, gray to tan. The darker pigment is diffused through the outer shell layer of the last two whorls, or two and one-half to three, in the larger specimens. The color is light brown to brownish black, being almost black along the carinae and the outer whorl face, especially on the last whorl. It is lighter and browner on the basal side. This pigment is completely soluble in dilute acid.

Naticopsis.—The color marked naticopsids to be discussed below came from two horizons, the Elm Creek and one that is probably Lueders. Those from the Elm Creek resemble those figured by C. A. White (1891, pl. 3, fig. 9) as *Naticopsis shumardi* McChesney. Possibly one-tenth of the hundreds of specimens collected by the writer show traces of coloration, but none conspicuously. Some of . ;ray to very dark gray. Some are u: ›lored, but in others the color .sts of growth lines slightly da .e main shell. Some of the shel. . tan. In many of these, groups o. .. .h-surfaced growth lines alternate wi.. groups of rougher ones. Such an instance is mentioned by Knight (1933, p. 361). This produces the illusion of differences in tint, but in other tan shells there is really a slight difference. These faint markings are not always confined to the last whorl. *In one shell only* there were remnants of parallel, *spiral*, color bands.

The figured naticopsids (pl. 123, fig. 6–8) come from a very limited outcrop of a highly fossiliferous marly limestone flag layer in the southern part of the county on the Stout ranch and is probably Lueders.

Besides the figured specimens the writer has several quite small naticopsids and four slightly larger, less perfect specimens, as well as a dozen fragments which show definite narrow brown bands that lie on the very surface of the shell. They are 0.1–.2 mm. wide. They follow the growth lines fairly closely, but waver slightly, as if painted on with an unsteady brush. Some of these bands seem to consist of several discrete lines. The shell itself is light brown to tan. The darker bands are confined to the last volution. Their darker pigment dissolves readily in dilute acid and faster than the color in the shell itself. Larger naticopsid shells from the same layer are light brown to tan in color, but only a few showed traces of colored lines, even when somewhat protected by matrix. Are color lines in this species confined to well-protected shells or to juveniles? Knight mentions a case of the latter (1933, p. 377–378). Here, however, both explanations seem to be valid.

The color patterns of naticopsids described by Knight (1933, 1944) and Zittel (1913, p. 522, 533–537) consist of colored axial bands or zigzag transverse bands; no simple transverse bands are mentioned.

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MANUSCRIPT RECEIVED FEBRUARY 15, 1957

EXPLANATION OF PLATE 123

All illustrations on this plate are unretouched photographs made by Mr. Frederick Kent of the University Photographic Service, Iowa City, Iowa. The specimens are in the A.H.K. collection, except No. 9, which belongs to young Bob Hayley.

FIG. *1–5*—*Straparollus* (*Euomphalus*) *cornudanus* Shumard. *1,2*, axial and basal views of 1135, ×1.1. *3,4*, axial and basal views of 173, ×1.1. *5*, axial view of 1148. *1*, ×1.1.

6–8—*Naticopsis* sp. 851a,b,c, ×6.

9—*Stenopoceras whitei* (?) Miller & Youngquist, ×1.

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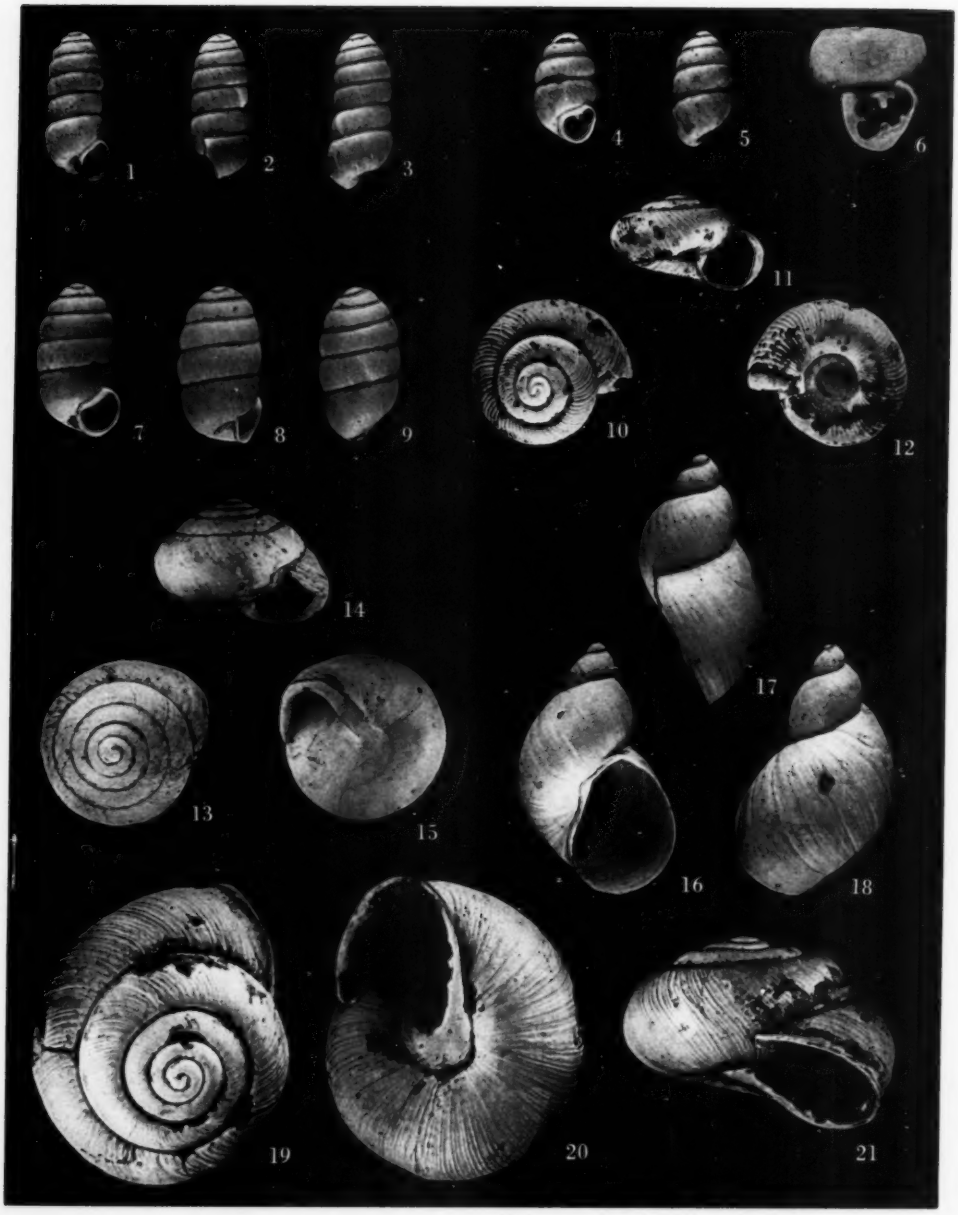
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JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 977–981, PL. 124, 1 TEXT-FIG., SEPTEMBER 1957

A TERRESTRIAL GASTROPOD FAUNA FROM FARMDALE (PLEISTOCENE) DEPOSITS IN NORTHWESTERN ILLINOIS[1]

A. BYRON LEONARD
Illinois State Geological Survey

ABSTRACT—Seven Pleistocene gastropod species are described from a recently reported occurrence of the Farmdale drift in northwestern Illinois. The species are: *Columella alticola* (Ingersoll), *Discus cronkhitei* (Newcomb), *Hendersonia occulta* (Say), *Pupilla muscorum* (Linné), *Succinea grosvenorii gelida* Baker, *Triodopsis multilineata algonquinensis* Nason, and *Vertigo modesta* (Say).

The faunule is unusual in that all the species are terrestrial and are accompanied by no aquatic forms even though the loess-like silts in which the gastropods were found are water deposited. Since the assemblage as a whole reflects a woodland habitat, the silts are interpreted as representing loess redeposited from a near-by wooded upland.

INTRODUCTION

THE existence of a post-Sangamon pre-Iowan drift, known as the Farmdale drift, recently has been reported in northwestern Illinois by Shaffer (1954, 1956), who called to my attention the occurrence of fossiliferous silts in deposits related to the Farmdale glacial advance and retreat. I visited the area in September, 1955, and collected bulk samples of the fossiliferous matrix in a gravel pit northeast of the city of Mt. Carroll in the NW¼ NE¼ sec. 9, T. 25 N., R. 5 E., Carroll County, Illinois. This paper is a report and discussion of the fossil gastropods recovered from that deposit.

TOPOGRAPHIC SETTING

The gravel pit from which the faunule came is within the valley of East Plum River, which drains the surrounding area. The relations of the fossiliferous deposits to East Plum River valley are shown on text-figure 1. The adjacent uplands have no till mantle, but according to Shaffer (1956), scattered erratics on the upland surface represent the Farmdale drift there. The gravel pit rests on a bedrock bench cut in Silurian dolomite, well above the channel level of East Plum River and well above a low terrace developed adjacent to the stream, but well below the adjacent upland surfaces.

The gravel pit exposes undisturbed Farmdale till, overlain by cross-bedded sand, gravel, and cobbles that are in turn covered by a stratum of sandy silt about 6 feet thick that contains lentils of sand and gravel. The top has been stripped in the course of removing overburden from the gravel.

[1] Publication authorized by the Illinois State Geological Survey.

EXPLANATION OF PLATE 124

FIG. *1–3—Columella alticola* (Ingersoll). Cat. No. 6P7000, ISGS. Ventral, lateral, and dorsal views, respectively. ×6.

4–6—Vertigo modesta (Say). Cat. No. 6P7001, ISGS. Ventral, lateral, and dorsal views, respectively. ×6.

7–9—Pupilla muscorum (Linné). Cat. No. 6P7002, ISGS. Ventral, lateral, and dorsal views, respectively. ×6.

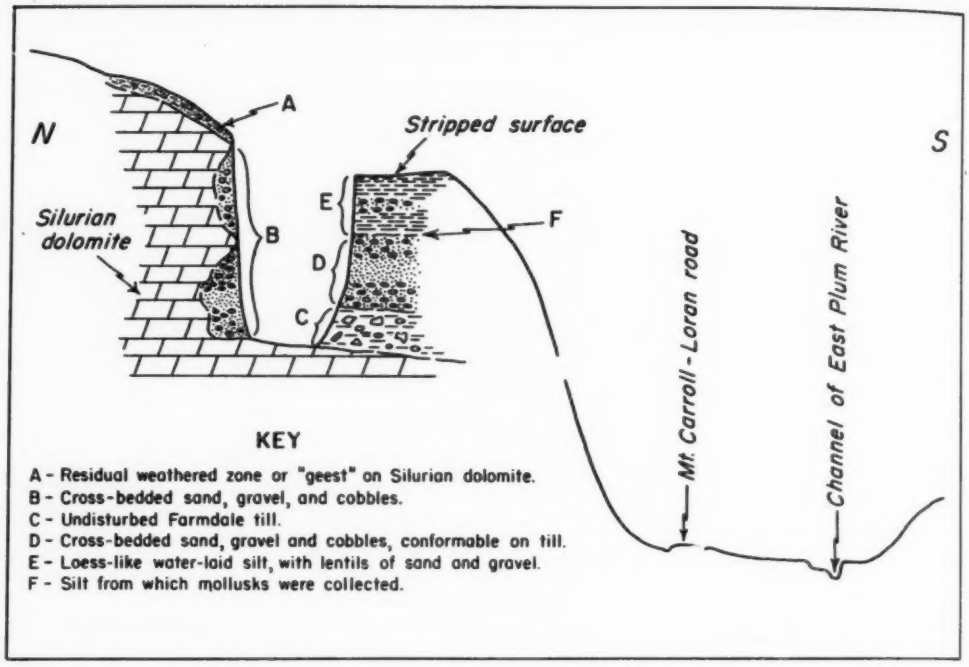
10–12—Discus cronkhitei (Newcomb). Cat. No. 6P7003, ISGS. Dorsal, lateral and ventral views, respectively ×5.

13–15—Hendersonia occulta (Say). Cat. No. 6P7004, ISGS, Dorsal, lateral, and ventral views respectively. ×4.

16–18—Succinea grosvenorii gelida Baker. Cat. No. 6P7005, ISGS. Ventral, lateral, and dorsal views, respectively. ×5.

19–21—Triodopsis multilineata algonquinensis Nason. (The figure is that of the holotype of *Polygyra multilinaeata wanlessi* Baker, Cat. No. P2358, ISGS, considered to be a synonym of *T. m. algonquinensis*). Dorsal, lateral, and ventral views, respectively. ×2.7.

Catalog numbers are those in the collection of late Cenozoic molluscs of the Illinois State Geological Survey at Urbana, Illinois.



TEXT-FIG. *1*—Diagrammatic representation of the relation of fossiliferous silts to Farmdale glacial sediments, and relation of gravel pit to East Plum River valley. Vertical scale greatly exaggerated.

FOSSILIFEROUS SILTS

The fossiliferous silts have the general appearance, color, and texture of coarse loess, although there is no reasonable doubt of their being water-laid in their present position. This is confirmed, not only by the occurrence of graveliferous lentils, but also by the presence of small pieces of chert distributed erratically throughout the silt. The silt is highly calcareous, pinkish yellow to pinkish gray, with concentrations of limonite and concretionary nodules of calcium carbonate. The lithologic series in the pit seem to be in conformable sequence; lithologic differences are judged to be related to facies changes produced by fluctuating stream regimen in the course of deposition.

GASTROPOD FAUNULE

The gastropod faunule in these sediments deserves attention because 1) it is the first to be reported from deposits directly related to the recently discovered Farmdale drift, and 2) the faunule itself, although small in numbers of species, possesses unusual characteristics.

The faunule comprises seven species of terrestrial (air-breathing) gastropods, most of which are no longer living in Illinois. The absence of aquatic gastropods in the assemblage is noteworthy, and is commented upon later in this paper.

COLUMELLA ALTICOLA (Ingersoll)
Pl. 124, fig. 1,2,3

The shell of the minute snail *Columella alticola* (Ingersoll), about 2.5 millimeters in length, occurs in large numbers in the deposit, exceeded only by the shells of *Succinea grosvenorii gelida* Baker. Extinct in Illinois and the central part of the United States, *C. alticola* still lives in mountainous regions of New Mexico, Colorado, Utah, Wyoming, and Montana, generally at elevations above 7000 feet, and farther north in Canada, where it is gradually replaced by *C. edentula* (Draparnaud).

C. alticola can be distinguished by its

small size, cylindrical shape, and simple peristome. The shell when mature has seven whorls. Immature shells can be distinguished from *C. edentula* only with difficulty; however, *edentula* has not been reported from Pleistocene deposits in Illinois.

C. alticola is known to occur in late Pleistocene deposits over a broad area (Leonard, 1950, 1952; Frye & Leonard, 1952), but its precise stratigraphic range is not yet known.

Discus cronkhitei (Newcomb)
Pl. 124, fig. 10,11,12

Discus cronkhitei (Newcomb) is represented in the Farmdale deposits by only a few, mostly fragmentary, shells from a total collection of several thousand shells. *D. cronkhitei* now lives in the Rocky Mountain region, in Canada, and in the eastern United States as far south as Kentucky. Pilsbry (1948, p. 600) mentions no records of the living snail in Illinois, but Baker (1939, p. 86) states, " . . . it appears to be confined to the northern half of Illinois," from which it may be assumed that the species still survives in the general area of the Farmdale deposits under discussion. It is a common species in Pleistocene deposits over all the central part of the United States. It has been reported from deposits of Kansan age (Leonard, 1950, p. 35), but its precise stratigraphic range and areal distribution in Pleistocene deposits in Illinois is not known.

The shell of *D. cronkhitei* has three and one-half to four whorls that are covered by conspicuous, transverse riblets. The diameter of the shell is a little more than five millimeters, slightly less than that of the shells of *D. macclintocki* Baker, which *D. cronkhitei* closely resembles.

Hendersonia occulta (Say)
Pl. 124, fig. 13,14,15

Hendersonia occulta (Say) is widely distributed in the loess from the central Great Plains to Indiana. It originally was described from Pleistocene loess deposits at New Harmony, Indiana. Subsequently, isolated and erratically distributed living colonies of *H. occulta* have been found, one of them near Athens in Menard County, Illinois (Baker, 1939, p. 39). *H. occulta* has been found in Pleistocene sediments that range in age from Kansan to Early Wisconsinan. The shell is easily recognized by its solidity, five flat-sided whorls, the disproportionately large last whorl, and lack of an umbilical opening in the base. The diameter of the shell ranges from six to seven millimeters.

Pupilla muscorum (Linné)
Pl. 124, fig. 7,8,9

The small shell of *Pupilla muscorum* (Linné) is widely distributed in the central United States in Pleistocene deposits that range in age from Kansan to (but not including) Late Wisconsinan, but its range is now limited to the northern United States, except that it occurs farther south at high altitudes in the Rocky Mountain region, Canada, and Alaska. It is widely distributed in the Old World—in Europe, northern and central Asia, and south to Iran and northern Africa.

The shell is nearly cylindrical, with six whorls; the length is little more than three millimeters. In the central Great Plains, the shells often bear one, occasionally two, and rarely three, weakly developed denticles (rounded bosses) in the peristome, but the Farmdale specimens, like typical shells from northern Europe, lack denticles.

Succinea grosvenorii gelida Baker
Pl. 124, fig. 16,17,18

Succinea grosvenorii gelida Baker is abundant in the Farmdale deposits, exceeding in number all other shells combined. The sub-species seems to be extinct. It is common in Pleistocene deposits in Illinois, and if it is synonymous with small succinieid shells of similar form reported by Leonard (1950, 1952) as *Succinea avara*, it is widely distributed over the central and southern Great Plains as well.

The shells of *Succinea* often are referred to described species with difficulty, but this small form, averaging about seven millimeters in length, is recognized with relative ease. The aperture is rounder than in most representatives of *Succinea* and the spire is narrower. *S. g. gelida* has from three to four whorls.

The precise stratigraphic range of *S. g. gelida* in Pleistocene deposits is not known, but it seems to have made its first appearance in Illinois no later than Illinoian time.

TRIODOPSIS MULTILINEATA ALGONQUINENSIS Nason
Pl. 124, fig. 19–21

The woodland species *Triodopsis multilineata algonquinensis* Nason is the largest of the shells in the Farmdale assemblage, but it is a small subspecies of the typical *multilineata*. Although the shells of *algonquinensis* are about 18 millimeters in diameter, shell diameters of the typical *multilineata* range upward to 30 millimeters. Baker (1928, p. 132) described this shell under the name of *Polygyra multilineata wanlessi*, but *wanlessi* seems indistinguishable from *algonquinensis*.

Because *T. m. algonquinensis* is represented in the Farmdale faunule by only a few fragmentary shells, the illustrations on plate 124 are those of Baker's type of *wanlessi*. Baker described *wanlessi* from "Yarmouth loess' in Fulton County, Illinois, but the stratigraphic placement of the deposit has not been confirmed, and the stratigraphic range of the subspecies remains unknown. The living snail has been reported from Illinois (Algonquin, McHenry County, is the type locality) and from Wisconsin, and I know of a colony in a marsh fed by artesian springs in Atchison County, Kansas.

VERTIGO MODESTA (Say)
Pl. 124, fig. 4,5,6

The minute shell of *Vertigo modesta* (Say) is little more than two millimeters in length; there are four and one-half to five whorls, and the peristome has five denticles (pl. 1, fig. 6). *V. modesta* is rare in the Farmdale faunule.

The living snail occurs in the northern United States, the Rocky Mountain region, Canada, and Alaska. It has not been reported from Illinois.

Typical *V. modesta* has only four denticles within the peristome; a subspecies, *parietalis*, which has five denticles arranged similarly to those in the Farmdale specimens, is common in the Rocky Mountain region, but there at least, the occurrence of the fifth (angular) denticle seems without geographic significance. Leonard (1950, p. 27) reported *V. modesta* from deposits of Kansan age in the central Great Plains; these shells have five denticles, but the series differs from those herein reported. The stratigraphic range of *V. modesta* in Pleistocene deposits in Illinois is not known; the relatively few records are from deposits of uncertain age.

ECOLOGICAL SIGNIFICANCE OF THE FAUNULE

It is remarkable that no species of aquatic gastropods occurs in the Farmdale faunule, especially since the deposits are waterlaid. Such deposits usually contain a sample of the local molluscan fauna, including both terrestrial and aquatic species. No valid explanation for the lack of aquatic molluscan species occurs to me, but the distribution of the glacial deposits suggests a working hypothesis.

The position of the fossiliferous silts, immediately overlying cross-bedded sand, gravel, and cobbles conformable on undisturbed till, suggests that the uplands had become repopulated with arboreal vegetation and a terrestrial molluscan fauna while the stream that occupied the contemporary valley antecedent to the valley of East Plum River was still too unstable to permit the reestablishment of an aquatic molluscan fauna.

The assemblage of terrestrial gastropods in the Farmdale deposits reflects a woodland habitat, or at least a woodland-border environment; typical prairie species are absent from the faunule. We may assume that the terrain was well watered, and that perhaps the local climate was slightly cooler than the present one, but this conjecture deserves no emphasis. The loess-like nature of the silts containing the shells, together with the terrestrial nature of the faunule, suggests redeposition of loess from a wooded upland situation into the valley-side position where the deposits now rest. This view is supported also by the occurrence in the silts of small fragments of carbonized material, scattered throughout. The Farmdale ice (except, possibly for tongues of ice in the valleys) must have retreated a significant distance in order for the flora and fauna to have become re-established, but the lack of any recognizable weathered zone in the sediments at any level suggests that the time interval since retreat was relatively brief.

STRATIGRAPHIC SIGNIFICANCE OF THE MOLLUSCAN ASSEMBLAGE

The molluscan assemblage reported here is not large enough nor varied enough to give it valid stratigraphic significance, especially since it lacks aquatic components. The known assemblage does not preclude the deposits being as old as Illinoian on the one hand, nor as young as Tazewellian on the other.

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MANUSCRIPT RECEIVED FEBRUARY 11, 1957.

JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 982, SEPTEMBER 1957

NOMENCLATURAL NOTES

NEW NAME FOR A BRACHYOPID LABYRINTHODONT

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In 1947 (p. 246) I proposed the name *Taphrognathus bradyi* for a brachyopid amphibian. The fifth volume of Neave, Nomenclator Zoologicus (1950) showed that this name had been previously given (Branson & Mehl 1941, p. 181) to a conodont. This prior use of the name makes it necessary to rename the amphibian, which is hereby designated *Hadrokkosaurus bradyi* (=*Taphrognathus bradyi* Welles 1947, *non Taphrognahus varians* Branson & Mehl 1941). The allusion is to the very large orbits shown in a skull collected later from Cameron.

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DATE OF SOME SPECIES OF *PENTREMITES*

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In a recent memoir on the blastoid genus *Pentremites* (GSA Mem. 69) Galloway and Kaska note that species described by E. O. Ulrich and by T. H. Clark are in conflict, and go on to say (p. 48): "Both descriptions were published in 1917, but which one first cannot be determined." Ulrich's work was treated as being the earlier, and Clark's species placed in synonymy.

Clark's paper (Mus. Comp. Zoöl. vol. 69, No. 9) was issued in August of 1917, according to its title page, and the contents page of the volume.

The paper by Butts in which Ulrich's depeared (Ky. Geol. Survey, Mississippian Formations of Western Kentucky) is dated 1917 on the title page, but 1918 on the spine. The copy in the library of the Geological Survey of Canada was received on November 22, 1918. It was not noticed in Nickles' Bibliography for 1917, but appears in that for 1918 (U. S. Geol. Survey Bull. 698).

Unless there is other evidence to show that the Kentucky work actually appeared before August 1917, Clark's paper would seem to be the earlier. Thus (accepting Galloway & Kaska's synonymies) *Pentremites altimarginatus* Clark would prevail over *P. biconvexus* Ulrich, *P. divergens* Clark over *P. princetonensis* Ulrich.

HENRYHOWELLA, NEW NAME FOR *HOWELLA* PURI, 1956

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Doctor Stuart A. Levinson has drawn my attention to the fact that *Howella* Puri, 1956 (Two New Tertiary Ostracode Genera from Florida; *Journal of Paleontology*, vol. 30, p. 274,275) is preoccupied by *Howella* Ogilby, 1899 (Proc. Linn. Soc. N. S. Wales, vol. 23, p. 734). I, therefore, propose *Henryhowella* Puri, n. name for *Howella* Puri, 1956 (not *Howella* Ogilby, 1899).

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AN ANASPID CRUSTACEAN FROM THE MIDDLE DEVONIAN OF NEW YORK

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THE archaic eumalacostracan order Anaspidacea is one of several major animal groups known from fossils many years before their living remnants were discovered. Recent anaspids were recognized first from Tasmania, and later from Victoria, Europe, and Africa, where they occur only in fresh water. The fossil representatives, from the Carboniferous and Permian, are from either paralic or limnic deposits.

Some years ago the writer collected a small, rather poorly-preserved anaspid from the Middle Devonian marine Moscow formation in central New York, but delayed recording the find in the hope that more material would turn up. After twenty years none has, and the unique specimen is here briefly noted.

Order ANASPIDACEA
Family ANASPIDIDAE
Genus PALAEOCARIS Meek and Worthen, 1865

Type species.—*P. typus* M. & W. 1865. Pennsylvanian, Illinois.

PALAEOCARIS? CUYLERENSIS, n. sp.
Pl. 125, fig. 1–4

Only parts of the trunk (parts of the thorax, abdomen, and tail fan) are distinguishable with certainty. Six (?7) abdominal somites tapering gently from a width of 2.5 mm. on the first to about 1.5 mm. on the last, the first five nearly equally long, about 1.5 mm. The sixth, bearing the tail fan, is apparently about twice as long as the others, but may actually be two somites. On the tail fan the telson is shield-shaped, about 1 mm. long and equally wide; the uropod exopodites are about 2.5 mm. in length, elongate oval; the endopodites a little shorter, much the same shape, with traces of a central strengthening fold. Anteriorly from the traces of the posterior thoracic somites are what appear to be remnants of thoracic appendages and an impression of the ventral anterior surface of the thoracic and cephalic region. The most anterior pair of elongate impressions may represent the bases of the antennules. Total length: 21 mm.

Holotype.—Cornell University No. 40020.

Horizon and locality.—Top of the Moscow formation (Windom member), 2 feet below base of the Tully limestone, in a quarry at elevation 1400 ft., 1.5 miles northwest of Deruyter, Madison County, and 2.5 miles northeast of Cuyler, Cortland County, central New York.

Remarks.—The last one or two abdominal somites and the tail fan are preserved as impressions of the ventral surface. The remaining abdominal and two or three posterior thoracic somites and traces of thoracic appendages are represented by flattened pyritic carbonizations. Figures 1 and 2 show the specimen under very low angle illumination; figure 3 is the same but with the specimen immersed in alcohol, which has enhanced the contrast of the carbonized remnants (the marks extending out from the abdominal somites are fracture patterns in the matrix, not traces of appendages, but it is presumed that these somites bore appendages).

In spite of the poor preservation, the resemblance of this specimen to *Palaeocaris* is unmistakable (*vide:* Meek & Worthen, 1868, p. 552, fig. A,B), especially with respect to the general form of the abdomen and tail fan. The similarity to the living *Anaspides* is equally striking, and a schematic dorsal aspect of this well-known living form, based on specimens from Tasmania kindly given the writer by F. S. Colliver (University of Queensland), is given in figure 5 of the plate. In size the new form is directly comparable with both *Palaeocaris* and *Anaspides*.

Fossil Anaspididae are known only from the Carboniferous of Europe and the United

States (Van Straelen, 1931; Roger, 1953, p. 318). One anaspid has been reported, but never fully described or figured, from the paralic Upper Devonian (psammites de Condroz=Famennian) of Belgium (Destinez, 1907, p. B66). Destinez merely indicated the similarity to *Palaeocaris* of a crustacean 30 mm. long and 4 mm. wide—much larger than *P. ? cuylerensis.*

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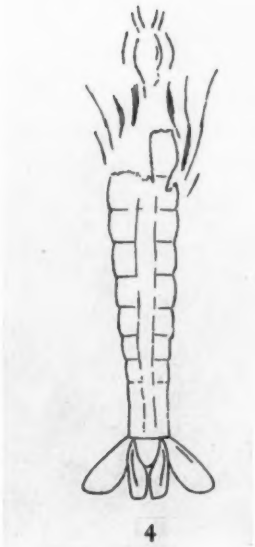
MANUSCRIPT RECEIVED FEBRUARY 19, 1957

EXPLANATION OF PLATE 125

FIG. *1–4—Palaeocaris ? cuylerensis*, n. sp., Upper Moscow shale, Cortland Co., N.Y.: *1*, holotype, ×1; *2*, holotype, ×3; *3*, holotype in, alcohol, ×3; *4*, sketch of apparent structures of holotype, ×3.

5—Anaspides tasmaniae Thomson, Recent, Lake Fenton, Tasmania; schematic dorsal aspect, ×3.

Partial cost of plate defrayed by the W. F. E. Gurley Foundation for Paleontology of Cornell University.



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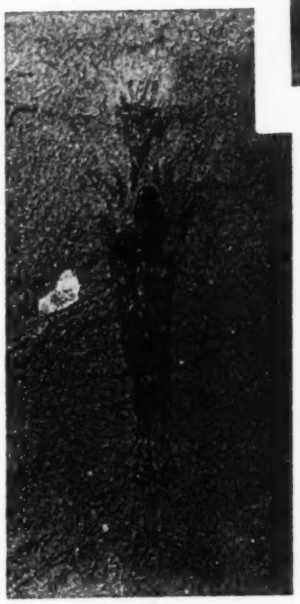

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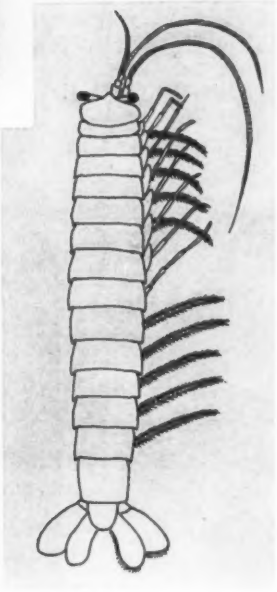

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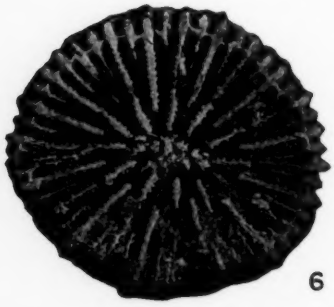
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JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 985–991, PL. 126, SEPTEMBER 1957

THREE NEW TERTIARY SCAPHOPODS, WITH A REVIEW OF THE EXTINCT WESTERN NORTH AMERICAN SIPHONODENTALIIDAE

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ABSTRACT—Six fossil species referable to the family Siphonodentaliidae are recognized from the Tertiary record of western North America. Three of these are described as new, *Cadulus* (*Platyschides*) *durhami*, *Cadulus* (*Platyschides?*) *addicotti*, and *Cadulus* (*Cadulus*) *mcfarlandae*. *Cadulus pusillus* (Gabb) is redefined and illustrated; all of the species are taxonomically reviewed.

INTRODUCTION

WEST coast paleontologists have generally given fossil scaphopods little attention. Although the class is not well represented in the Mesozoic sediments of western North America, their remains are abundant locally in the Tertiary deposits, especially in the Paleogene. Inasmuch as well preserved individuals usually are required for accurate identifications, and complete fossil specimens are the exception rather than the rule, many of the records cited in the literature have been based on field observations and fragmental specimens. As a consequence, some of the recorded specific identifications are questionable, or the occurrences have been given only generic assignments. It is the purpose of this paper to review the Tertiary species of western North America referable to the family Siphonodentaliidae.

Of the 17 west coast Tertiary scaphopod species, only six are representatives of this family, and three of these are described below as new species. The known distribution of the species is, Eocene: *Cadulus* (*Platyschides*) *gabbi* Sharp & Pilsbry, *Cadulus* (*Cadulus*) *meganosensis* Palmer, *Cadulus* (*Cadulus*) *mcfarlandae*, n. sp.; Oligocene: *Cadulus* (*Platyschides*) *durhami*, n. sp.; Miocene: *Cadulus* (*Platyschides?*) *addicotti*, n. sp.; and Pliocene: *Siphonodentalium? arcticus* (Dall). Vokes (1936) has recorded an unnamed cadulid from the Capay (Eocene) of California; the specimens are too poorly preserved to justify naming. In addition to the apparently extinct forms, some of the living eastern Pacific species appear to have originated in the Pliocene; these include: *Cadulus* (*Gadila*) *fusiformis* Pilsbry & Sharp and *Cadulus* (*Gadilopsis*) *perpusillus* (Sowerby). Other Recent species are known to occur in the Pleistocene.

Considerable confusion has existed concerning the identity of "*Dentalium pusillum*," (= *Cadulus* (*Platyschides*) *gabbi* Sharp & Pilsbry), described by W. M. Gabb, in 1864. Records of this species have been referred to the "Cretaceous," Paleocene, and Eocene deposits of western North America. Gabb's inadequate original description and poor illustration have been supplemented, after examination of the type specimens, with a redescription and drawings of the lectotype (pl. 126, fig. 5) and a paratype (pl. 126, fig. 1). This species appears to be

EXPLANATION OF PLATE 126

FIG. *1,5—Cadulus* (*Platyschides*) *gabbi* Sharp and Pilsbry. *1*, paratype, ×5. *5*, lectotype, ×5.
2—Cadulus (*Platyschides?*) *addicotti* Emerson, n. sp., holotype, ×5.
3—Cadulus (*Platyschides*) *durhami* Emerson, n. sp., holotype, ×5.
4—Cadulus (*Cadulus*) *mcfarlandae* Emerson, n. sp., holotype, ×25.
6–9—Caryophyllia mcglameryae, n. sp., Holotype, A.M.N.H. 28028, ×4.5. *6*, view of calice. *7*, side view of corallum. *8*, basal view showing scar of attachment. *9*, oblique side view.
10–12—Lophelia tubaeformis, n. sp. *10*, holotype, A.M.N.H. 28030, ×3.3, calicular view of lower corallite. *11*, holotype, ×2.0, side view of corallum showing mode of budding. *12*, paratype. A.M.N.H. 28031/1, ×3.3, view of calice.

confined to the "Tejon" Stage (Eocene)[1] of Washington and California.

Acknowledgments.—It is a pleasure to acknowledge the assistance received in the completion of this study. Horace G. Richards, Academy of Natural Sciences of Philadelphia, Bernhard Kummel, Museum of Comparative Zoology at Harvard College, and Joseph H. Peck, Jr., University of California Museum of Paleontology, searched the collections of their respective institutions for Gabb's scaphopod material. J. Wyatt Durham, Department of Paleontology, University of California, critically read the manuscript and kindly permitted the writer to describe the new species in the collection of the University of California Museum of Paleontology. The drawings were made by Joan Sischo, scientific illustrator, University of California Museum of Paleontology and Chester S. Tarka, staff artist, American Museum of Natural History.

Abbreviations for institutional names.—

A.N.S.P. Academy of Natural Sciences of Philadelphia.
C.A.S. California Academy of Sciences (San Francisco).
U.C.M.P. University of California Museum of Paleontology (Berkeley).
U.W. University of Washington (Seattle).

SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA
Class SCAPHOPODA
Family SIPHONODENTALIIDAE
Genus SIPHONODENTALIUM M. Sars, 1859

Type species.—By monotypy, *Dentalium vitreum* M. Sars, 1851, not Gmelin, 1791 = *Siphonodentalium lobatum* (Sowerby), 1860, (Emerson, 1952, p. 301).

SIPHONODENTALIUM (?) ARCTICUS (Dall, 1920)

Cadulus arcticus Dall, 1920, p. 30, pl. 5, fig. 8. Grant and Gale, 1931, p. 439.

Original description.—

Shell small, slender, arcuate, smooth, with circular section and no swelling ventrally; the color is white with narrow translucent zones irregularly disposed. Length, 7 millimeters; diameter at anterior end, 0.75 millimeter; height of arc described by the ventral curve, 1.2 millimeters.

Remarks.—Dall's very brief description and poor illustration leave considerable doubt as to the true identity of this species. Though the lack of an anterior contraction of the tube suggests the genus *Siphonodentalium*, the irregular form of the tube recalls certain serupulid worm tubes. Through the courtesy of F. Stearns MacNeil paratypes contained in the U. S. Geological Survey collection were loaned the writer. The paratypic specimens are poorly preserved fragments embedded in a shale matrix. The largest fragment referable to Dall's description and figure measures 8.3 mm. in length and possesses a fractured surface and irregular outline, features which characterize the figured holotype, (Dall, 1920, pl. 5, fig. 8). Although the state of preservation of the paratypes precludes definite generic assignment, the specimens may be questionably referred to *Siphonodentalium*. In superficial appearance it appears to be close to *Siphonodentalium* (*Pulsellum*) *ozawaki* Yokoyama, a Japanese species that is recorded to range from the Pliocene (Sawane) to the Recent.

Range.—"Pliocene."

Occurrence.—Known only from type locality.

Type locality.—"Carter Creek, in the Camden Bay region of the Arctic coast, 1 mile from the coast."

Type depository.—U.S.N.M., U. S. Geological Survey collection, holotype 324322; paratypes unnumbered.

Genus CADULUS Philippi, 1844

Type species.—By monotypy, *Dentalium ovulum* Philippi, 1844.

Subgenus CADULUS
CADULUS (CADULUS) MCFARLANDAE
Emerson, n. sp.
Pl. 126, fig. 4

Description.—Shell minute, short, obese with area of greatest inflation located slightly posterior of mid-section of tube. Tube attenuated at both ends with greater constriction at posterior end, slightly curved; convex outline strongly arched and swollen

[1] Time units are based on the Pacific coast metazoan chronology (Weaver, *et al.*, 1944).

centrally, concave outline inflated centrally. Surface polished, opaque and white. Orifices circular in outline, apical rim simple. Measurements: holotype 37590, length 1.1 mm., diameter of apertural orifice 0.2 mm., diameter of apical orifice 0.2 mm. None of the specimens examined exceeds 1.3 mm. in length.

Remarks.—No fossil or living west American species approaches this tiny species in degree of bulbous swelling. *Cadulus* (*Cadulus*) *exiguus* Watson from deep water off Culebra Island, Puerto Rico superficially resembles this species, but is a larger form having a less pronounced medial swelling.

The present species commonly occurs in association with *Cadulus* (*Cadulus*) *meganosensis* Palmer. Modern representatives of the nomintypical subgenus of *Cadulus* are largely restricted to moderately deep water.

Range.—Early Eocene.

Occurrence.—Capay formation, "Vacaville shale."

Records.—California, 4± miles west of Winters, Yolo Co., Capay Quad., Capay formation, U.C.M.P. A-1529, 8 specimens; U.C.M.P. A-1800, same as A-1529, 5 specimens; U.C.M.P. A-3072, same as A-1529, 2 specimens; Ualtis Creek, southwest of Dunns Peak, Solano Co., Napa Quad., "Vacaville shale," U.C.M.P. 3078, 1 specimen; U.C.M.P. A-3358, same as A-3078, 2 specimens; A-3358, same as A-3078, 5 specimens (types).

Type locality.—Shales exposed along Ualtis Creek southwest of Dunns Peak, Vaca Valley, Solano Co., California, U.C.M.P. loc. A-3365, Eocene, "Vacaville shale," Capay formation. Herdis Bentson McFarland, collector.

Type depository.—U.C.M.P., holotype 37590, paratypes 37591–37594.

CADULUS (CADULUS) MEGANOSENSIS Palmer, 1923

Cadulus meganosensis Palmer, 1923; p. 303, pl. 54, fig. 5, ("Vaca Valley"). Merriam & Turner, 1937, p. 101, ("Capay Valley"). Keen & Bentson, 1944, p. 123. Weaver, 1949, p. 57, ("Capay shale, north of Carquinez Strait").

Original description.—

Shell small; surface smooth and polished; inflated; maximum inflation slightly to one side of middle. Aperture oval at end nearest greatest inflation but more nearly circular at opposite end. Dimensions of holotype: length 1.64 mm.; maximum width .92 mm.

Remarks.—Palmer (1923, pl. 54, fig. 5) records this species to be abundant at the type locality and figures the holotype, a poorly preserved, incomplete specimen. An examination of numerous specimens in the University of California Museum of Paleontology collections from eight early Eocene localities shows the posterior rim to be ornamented with many minute, narrow slits, which form delicate apical teeth. The posterior orifice is circular in outline and about a third as large as the semi-ovoid anterior orifice. The extremely inflated, centrally obese outline of the tube serves to readily distinguish this species from the known west American forms with the exception of *Cadulus* (*Cadulus*) *mcfarlandae*, n. sp. The latter species possesses a much smaller, strongly arched tube and a simple apical rim.

Some of Weaver's (1949, p. 57) records of *Cadulus* (*Cadulus*) *meganosensis* from the Capay shale of northern California may be referable to *Cadulus* (*Cadulus*) *mcfarlandae*, n. sp.; the present writer has not had an opportunity to study the material.

Range.—Early Eocene.

Occurrence.—Capay formation, "Vacaville shale."

Records.—California, Capay Valley, Yolo Co., "Capay formation," U.C.M.P. A-1313 (Merriam and Turner, 1937); Ualtis Creek, Vaca Valley, Solano Co., "Middle Eocene shales" ["Vacaville shale" Merriam and Turner (1937, p. 101)], U.C.M.P. 3573 (Palmer, 1923); 3± miles north of Brooks in Smith Canyon opposite abandoned Tracred railroad station, Rumsey Quad., Yolo Co., Capay formation, U.C.M.P. A-3363, 3 specimens); Ualtis Creek, southwest of Dunns Peak, Solano Co., Napa Quad., "Vacaville shale," U.C.M.P. 3078, 9 specimens; U.C.M.P. A-3356, same as A-3078, 3 specimens; U.C.M.P. A-3358, same as A-3078, 6 specimens; Ualtis Creek, Vaca Valley, Solano Co., "Capay Shale," U.W. 2602, (Weaver, 1949); Potrero Hills, Solano Co., "Capay Shale," U.W. 2544 (Weaver, 1949); Browns Valley, north of Napa, Napa Co., U.W. 3029 (Weaver, 1949).

Type locality.—Ualtis Creek, south of Dunns Peak, Vaca Valley, Solano Co., California, U.C.M.P. loc. 3573, Eocene, "Vaca-

ville Shale." Capay formation.

Type depository.—U.C.M.P., holotype 30601.

Subgenus PLATYSCHIDES Henderson, 1920

Type species.—By original designation, *Cadulus grandis* Verrill, 1884.

CADULUS (PLATYSCHIDES) GABBI Sharp & Pilsbry, 1898
Pl. 126, fig. 1,5

Dentalium (Ditrupa?) pusillum Gabb, 1864, p. 139, pl. 21, fig. 99, (". . . northeast of Martiñez (Division B) [Eocene]; . . . Alizos Creek, near Fort Tejon [Eocene]; Tuscon Springs [Tehama Co., Calif.])"

Gadus pusillus, Gabb, 1867, p. 303, ("Upper Division, Martinez and Vicinity of Fort Tejon"). Gabb, 1869, p. 230, ("Tejon Group, Martinez, Tejon"). Heilprin, 1882, p. 198, ("Martinez and vicinity of Fort Tejon"). Meyer, 1884, p. 111, ("Tejon group, Martinez, Cal.").

Siphonodentalium pusillum, Cooper, 1888, p. 291, "Cret. B, [Eocene] Martinez, Contra Costa Co.; Tejon, Kern Co.").

Gadus pusillus, Stanton, 1896, p. 1021, ("Tejon strata," near Clayton and Summersville, California).

Cadulus gabbi Sharp & Pilsbry, 1898, p. 236.

Siphonodentalium pusillum, Arnold, 1906, p. 15, ("Tejon formation").

Cadulus pusillus, Dickerson, 1915, p. 43,49, ("Type Tejon and Cowlitz phase"). Dickerson, 1916, p. ?372,?378,?407,421, in part, not p. 426,432,447 (U.C.M.P. loc. 1817). ("Type Tejon," [p. 421], references to occurrences in "Basal Tejon strata south of Mount Diablo," [list opp. p. 372], "Balanophyllia Variabilis Zone [Tejon Stage] south of Mount Diablo" [p. 378], and "Siphonalia Sutterensis Zone" [Gaviota Stage] near Marysville Butts [p. 407] were not verified). Weaver, 1916, p. 12, ("Marine Tejon," Lower Cowlitz River Valley, Oregon).

Cadulus gabbi, Anderson & G. H. Hanna, 1925, p. 146, pl. 11, fig. 11, ("Type Tejon"). Keen & Bentson, 1944, p. 123.

Cadulus sp. cf. *C. gabbi*, Stewart, 1946, tab. 1, ("Avenal sandstone of Reef Ridge").

Original description.—

> Shell small, gently curved. Section circular. Slightly widest near the mouth; sides, from the widened portion, running nearly parallel to the aperture, or very slightly approaching. Surface polished. Length. .38, inch; greatest width, .05 inch, Gabb, 1864.

Supplementary description.—Shell fairly solid, moderately curved, with area of maximum diameter at about the anterior third of tube. Width of tube variable with individuals. Convex arc nearly flat along the anterior half of tube, only slightly inflated in region of greatest diameter, i.e. above the area of apertural constriction; swelling gradual, tube unmarked by a prominent hemisphere. Anterior aperture noticeably constricted, slightly oblique, circular in outline. Tube slightly attenuated posteriorly, apical orifice constricted, commonly possessing an internal ring, circular in outline. Apical characters not preserved. Surface of tube vitreous in fresh specimens, commonly yellow-brown. Measurements: lectotype, length 9.8 mm. (incomplete), diameter of apertural orifice 1.3 mm., diameter of apical orifice 1 mm. (estimated); paratype, length 9.4 mm. (estimated), diameter of apertural orifice 0.8 mm. (estimated); paratype, length 9.8 mm. (incomplete), diameter of apertural orifice 1.5 mm. (estimated), diameter of apical orifice 0.4 mm. (estimated); paratype, 6.0 mm. (incomplete), diameter of apical orifice 0.9 mm. (fragment of apical portion).

Remarks.—The first locality reference cited by Gabb (1864) is, "Several specimens found northeast of Martinez (Division B)." A search for possible type material resulted in the loan by Dr. H. G. Richards of one unnumbered lot of four specimens from the Gabb collection now contained in the Academy of Natural Sciences of Philadelphia. The label accompanying the specimen reads, "*Gadus pusillus* Gabb, Tejon Group, Martinez, California, W. M. G. [abb]," see citation to Gabb (1869). These would appear to be part of Gabb's original material and the only specimens remaining extant. The best preserved and most complete specimen is selected here as the lectotype, pl. 126, fig. 5, and forms, together with the paratypes, the basis for the supplementary description given above.

Gabb's (1864) figure appears to be inaccurate. No mention is made in his original description of a marked hemispherical bulge as depicted in the drawing, nor do any of the syntypes possess a perceptible tubular swelling. The specimen illustrated by Anderson & Hanna (1925, pl. 11, fig. 11) from the type Tejon (C.A.S. locality 711) closely resembles the lectotype. Individuals of a large series of specimens from the Cowlitz formation (U.C.M.P. locality A-1543) fall within the range of variation exhibited by the syntypes.

As indicated by the following measurements of specimens from the "basal Cowlitz" (U.C.M.P. locality A-1543), this species varies considerably in the stoutness of the tube: hypotype 37578 has length 10.8 mm. (incomplete), diameter of apertural orifice 1.9 mm., diameter of apical orifice 1.2 mm.; hypotype 37579 has length 8.1 mm. (nearly complete), diameter of apertural orifice 1.1 mm., diameter of apical aperture 0.8 mm.; hypotype 37580, length 11.6 mm. (incomplete), diameter of apertural orifice 1.9 mm., diameter of apical orifice 1.1 mm.; hypotype 37581, length 9.2 mm. (nearly complete), diameter of apertural orifice 1.5 mm., diameter of apical orifice 0.7 mm.

The character of the apical features is uncertain. Fragmental specimens from the Cowlitz formation appear to have two shallow slits on the lateral faces and possibly two very shallow slits on the concave face.

This species is abundant locally in rocks of the "Tejon" Stage of Washington and California. The state of preservation, however, is often poor, and the extraction of specimens from a well-indurated matrix is usually difficult.

Compared to the known west American fossil species referable to *Platyschides*, *Cadulus durhami*, n. sp., from the Oligocene of Washington has a much stouter, proportionally shorter tube, and *Cadulus addicotti*, n. sp., from the Miocene of California has a smaller, less posteriorly attenuated tube. The fragmental specimens described by Vokes (1936) from Capay Stage (Eocene) of California may represent the present species, but specific assignment must await examination of better material.

Range.—[?Paleocene], Eocene. No authentic Paleocene records were detected.

Occurrences.—"Tejon" Stage of Washington and California; Cowlitz formation, Lewis Co., Washington, Tejon group of California, Eocene.

Verified records.—Washington, W. bank of Cowlitz River, Lewis Co., Olequa Quad., "basal Cowlitz," U.C.M.P. A-1543. W. bank of Cowlitz River, Lewis Co., Olequa Quad. SW ¼ SE ¼ 528, T 11 N., R 2W, type locality of "Lower Cowlitz," U.C.M.P. A-8726. W. bank of Cowlitz River, ½ mi. E. of Vader, "Marine Tejon" [=Cowlitz fm.], U.W. 1 and 239 (Weaver, 1916). California, South of Mount Diablo, Contra Costa Co., "Basal Tejon" [=? "Domengine stage"] (Dickerson, 1916). Northwest of Martinez, Contra Costa Co., "Cretaceous, Division B, Tejon Group" [=Eocene] (Gabb, 1864, 1869; Cooper, 1888) type locality. Alizos Creek [Live Oak Creek], near Fort Tejon, Kern Co., Tejon fm. (Gabb, 1864, 1867, 1869; Dickerson, 1915, 1916; Anderson & Hanna, 1925, C.A.S. loc. 244). E. side of Grapevine Creek, Kern Co., Tejon fm. (Anderson & Hanna, 1925, C.A.S. loc. 711).

Type locality.—Northeast of Martinez, [Contra Costa Co., California] (Division B.), "Cretaceous" [=Eocene, precise locality unknown].

Type depository.—A.N.S.P., unnumbered lectotype, here illustrated, pl. 126, fig. 5, and 3 paratypes, 1 here illustrated, pl. 126, fig. 1.

Cadulus (Platyschides) durhami Emerson, n. sp.
Pl. 126, fig. 3

?Cadulus sp., Dunham, 1944, p. 120,191, (Jefferson Co., Washington, U.C.M.P. A-3703).

Description.—Shell small, moderately curved, area of maximum diameter situated slightly posterior of mid-section of tube. Convex arc nearly straight; tube slightly inflated in equatorial area, swelling gradual; tube moderately attenuated posteriorly, (see pl. 126, fig. 3). Surface smooth, porcellaneous. Apertural orifice oval; apertural rim slightly oblique. Apical orifice circular; apical rim incomplete, apparently with shallow notches. Measurements: holotype, length 8.5 mm., diameter of apical orifice 0.7 mm.; paratype, length 7.2 mm. (incomplete, specimen imbedded in matrix).

Remarks.—Of the known fossil west American forms, this species most closely resembles *Cadulus* (*Platyschides*) *gabbi* Sharp and Pilsbry, but differs in having a smaller, more fragile and inflated tube. None of the living eastern Pacific species approaches this species in specific characters. *Cadulus* (*Platyschides*) *agassizi* Dall, a common inhabitant of Florida waters, superficially resembles this species in general outline of the tube, but possesses a larger shell with greater posterior attenuation.

Two poorly preserved, somewhat distorted, internal molds of a similar cadulid

recorded by Durham (1944) from the Quimper sandstone (Oligocene) of Washington are referred questionably to this species. The outline of the less compressed of these resembles this species. The poor state of preservation, however, precludes a definite specific assignment. These specimens measure 7.5 mm. in length (hypotype U.C.M.P. 35494; incomplete) and 8.1 mm. in length (hypotype U.C.M.P. 35494a; incomplete), respectively.

Range.—Oligocene.

Occurrences.—Known from the type locality and questionably from the "*Turritella olympicensis* zone," Jefferson Co., Washington, "Quimper sandstone," U.C.M.P. A-3703 (Durham, 1944).

Type locality.—Grays Harbor Co., Washington, U.C.M.P. loc. A-8723, Oligocene, "Lincoln" Stage, type Porter fauna, Lincoln formation. J. Wyatt Durham and party, collectors.

Type depository: U.C.M.P., holotype 37582, here illustrated, pl. 126, fig. 3; paratype 37583.

CADULUS (PLATYSCHIDES?) ADDICOTTI Emerson, n. sp.
Pl. 126, fig. 2

Description.—Shell minute, slender, slightly curved, with area of maximum diameter at about the anterior third. Tube not markedly inflated; convex outline nearly straight, lacking perceptible convexity in area of greatest diameter. Surface smooth, with growth lines only. Anterior aperture constricted, margin slightly oblique; anterior portion of tube slightly compressed laterally to form an oval outline to the oral orifice. Apical orifice circular; characters of apical rim uncertain. Irregularities of rim of the fragmental specimens suggest probable affiliation with *Platyschides*. Measurements: holotype 37584, length 5.2 mm. (incomplete), diameter of apertural orifice 0.9 mm., diameter of apical orifice 0.8 mm. (incomplete); 5 paratypes 37585–37589, length: 5.7 mm. (incomplete), 4.1 mm. (incomplete), 3.7 mm. (incomplete), 2.7 mm. (fragment of apical portion), 3.4 mm. (fragment of apical portion).

Remarks.—The small size, slight equatorial swelling, and weakly attenuated tube serve to distinguish this from the other known west American fossil species. It appears to be most closely allied to *Cadulus* (*Platyschides*) *austinclarki* Emerson, a shallow water species living in the tropical eastern Pacific, but differs in having a less attenuated and more weakly inflated tube.

Range.—"Middle" Miocene.

Occurrence.—Upper member of Olcese sand.

Records.—Known from the type locality and 20 feet stratigraphically below the type locality in a measured section, U.C.M.P B-1637, 2 specimens.

Type locality.—1± mile southwest of mouth of Kern River Gorge, in east bank of east fork of northwest trending gully, about 100 feet below Round Mountain silt contact, [center SW ¼ sec. 6, T. 29 S. R. 30 E., M.D.B.M.], Kern Co., California, Miocene, "Temblor" Stage, Upper member of Olcese sand. Warren O. Addicott, collector.

Type depository.—U.C.M.P., holotype 37584, here illustrated, pl. 126, fig. 2; 5 paratypes 37585–37589.

CADULUS sp. indet., Vokes, 1936

Cadulus pusillus, Dickerson, in part, 1916, p. 426,427,432,447, not p. 372,378,407,421, (U.C.M.P. loc. 1817). Not *Cadulus pusillus* (Gabb), 1864 = *Cadulus gabbi* Sharp and Pilsbry, 1898.

Cadulus (?) new species, Vokes, 1936, p. 30,106, pl. 16, fig. 32, (Urruttia Canyon, California, U.C.M.P. loc. 1817).

Remarks.—Vokes (1936) noted fragmental specimens of a small cadulid from the "Lower Zone" of the Arroyo Hondo formation (Eocene). Unfortunately, all of the specimens lack the apical portion of the tube, and may not be referred to a subgenus. The outline of the illustrated specimen (Vokes, 1936, pl. 16, fig. 32), however, suggests a probable affiliation with *Platyschides* or *Polyschides*. The recorded specimens are smaller than the apparently similar Eocene species, *Cadulus* (*Platyschides*) *gabbi* Sharp and Pilsbry, and are larger and more obese than *Cadulus* (*Platyschides?*) *addicotti*, n. sp., from the Miocene.

Range.—Eocene.

Occurrence.—Known only from the "Cerros member" Urruttia Canyon, Fresno Co., California, Eocene, Capay Stage, Lodo formation.

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NEW SPECIES OF CARYOPHYLLIID CORALS FROM THE GULF COAST TERTIARY

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ABSTRACT—Two species of coral collected from the Gulf Coast Tertiary in preparation for a comprehensive study have proved to be new. *Caryophyllia mcglameryae* from the Lisbon formation of Albama is a representative of a ubiquitous genus not common in the Eocene of that area. *Lophelia tubaeformis* from a coral bearing boulder along the Flint River, Georgia, represents the second known occurrence of this genus as a fossil.

Two new species of Caryophylliidae were among Tertiary corals collected along the Gulf Coast in preparation for a systematic review and a distribution study. *Caryophyllia*, a genus not common in these sediments, was collected from the basal Lisbon formation of Alabama. Further collecting in the Lisbon formation yielded information on the distribution of this and other species, and indicated problems which will be encountered as more extensive and detailed studies of these faunas are continued.

A second species, of the genus *Lophelia*, a deep water coral, was collected in association with reef corals from the boulders along the Flint River, south of Bainbridge, Georgia. This species is of particular interest because the only previous description of the genus *Lophelia* as a fossil has been a species occurring in New Zealand. Collections from the Flint River are of particular importance as the completion of the Jim Woodruff Dam has flooded most of the better known localities of Vaughan and Dall.

DESCRIPTIONS

CARYOPHYLLIIDAE

CARYOPHYLLIA Lamarck, 1801

CARYOPHYLLIA MCGLAMERYAE, n. sp.

Pl. 126, fig. 6–9

Corallum low, bowl-shaped, with a flattened base, and only slightly compressed. The central portion of the base of all specimens bears a scar of attachment, or the remnants of the object to which the coral was attached. Various specimens were attached to pectinid pelecypods, oyster shells, bryozoans or small pebbles. A narrow rim of stereome was deposited about the margins of the basal attachment, and in some, this rim nearly envelops the attachment. About the rim, the corallum expands rapidly, nearly horizontally, bending almost sharply to the low vertical wall of variable height. Exterior of corallum nonepithecate, costate, the costae being of about equal size, wider than the interspaces, and with minute granules scattered on their lateral faces. On the lower portion of the wall, only costae corresponding to the first and second cycle of septa are present, but as the angulation is reached costae corresponding to all septa are present. Calice nearly circular, shallow, the septa sloping gently downward. Septa are slightly exsert, the upper margin being nearly horizontal or arched gently upward. Septa are heavily granulose laterally and are somewhat thicker distally, principally in older specimens, younger ones having nearly plane septa. The basic arrangement is four cycles (48 septa) in six systems, but in larger specimens, a greater number of septa are present, as many as 12 septa of the fifth cycle appearing, but without addition of pali. First and second cycle septa reach and join the columella. Third cycle septa are joined by the fourth deep in the calice and about three-quarters of the way to the columella, giving rise to pali which form a single crown. Pali are thin, straight and laterally densely granular, and often remain united to the third cycle septa nearly to the upper level of the columella. The columella is small, and its surface has the appearance of a number of granulose rods rather than the curled laths typical of the caryophyllids.

MEASUREMENTS IN MM.

	Diameters of the Calice	Height	Septa
Holotype			
A.M.N.H. 28028	9.5× 9.1	7.8	50
Paratypes			
A.M.N.H. 28029/1	8.3× 8.1	5.6	48
A.M.N.H. 28029/2	11.6×10.9	5.7	54
A.M.N.H. 28029/3	13.7×13.3	6.7	approx. 51
A.M.N.H. 28029/4	14.8×11.0	9.6	approx. 60

Type specimens.—Holotype, A.M.N.H. 28028; paratypes A.M.N.H. 28029/1–28029/4. The lower four feet of the Lisbon formation along a road cut on Alabama Highway 17, on the south bank of Souwilpa Creek, about 4 miles south of Gilbertown, Choctaw County, Alabama. Collected by D. F. Squires, W. Heaslip and Miss Winnie McGlamery, August, 1955 and by D. F. Squires and E. J. Hawkins, July, 1956. The section there has been described in detail by Toulmin et al. (1951, p. 111).

Remarks.—Particularly characteristic of the species is its shape, a departure from the more common turbinate or subcylindrical form of the species, as is the relatively small size of the corallum and the rod-like character of the columella.

Two other species of *Caryophyllia* have been described from the Eocene of the Gulf Coast: *C. dalli* Vaughan, known from the Jackson of Louisiana and Arkansas, and *C. texana* Vaughan, from the "Lower Claiborne," San Augustine, Texas. *Caryophyllia dalli* Vaughan, 1900 (p. 110, pl. 9, fig. 2,2a, 2b,2c) is subconical, tall, often cornute and has prominent flange-like costae on the upper portion of the corallite. All of these characters serve to differentiate it sharply from *C. mcglameryae*. *Caryophyllia texana* Vaughan, 1900 (p. 111, pl. 9, fig. 3,4) is cornute to conical, bears a short pedicel, and the costae are alternating and distally granulated. These features separate it from *C. dalli*, and the shape and alternating costae distinguish it from *C. mcglameryae*.

Caryophyllia colei Wells, 1945 (p. 10, pl. 2, fig. 19–22) from the Eocene Upper Scotland formation of the Barbados Islands is similar to *C. texana*, having alternating costae and approximately the same proportions, but more septa. Wells notes that specimens in the collections from two of the localities differ from others of the same horizon in having elongate, strongly cornute coralla, but characters of the pali and septa were not conspicuous enough to warrant discussion. These elongate individuals (Wells' pl. 2, fig. 19,20) are clearly different, but the others (cf. his fig. 21) most closely resemble the new species, being short turbinate forms with the diameter of the calice nearly equal to the height of the corallum. *C. mcglameryae* is not as tall and lacks the compressed calice of the Barbados form as well as the alternating costae.

Vaughan & Popenoe (1933) described three species of *Caryophyllia* from the Midway of Texas, all of which differ from *C. mcglameryae* in having a conical or trochoid corallite with a narrow base, in the greater development of columella, and in having costae of relatively great breadth. *C. mediavia* and *C. dumblei* both have about 40 septa and *C. constricta* has about 24 as contrasted with the four complete cycles of septa found in all specimens of *C. mcglameryae*.

Several species of *Caryophyllia* described from the Oligocene of Washington by Durham (1942), (*C. blakeleyensis*, *C. woodmanensis*, and *C. wynoocheensis*), are quite different from *C. mcglameryae*, all having trochoid coralla and flange-like costae.

The species is named for Miss Winnie McGlamery of the Alabama Geological Survey, who has contributed much to the knowledge of Alabama Tertiary stratigraphy and paleontology and who was a gracious guide and field partner during the season of 1955.

NOTES ON DISTRIBUTION

At present the species has been collected only at the type locality where it is associated with a fauna composed of *Endopachys maclurii* (rare), *Flabellum cuneiforme* (common), *Balanophyllia* type 1 (common), *Discotrochus orbignyanus* (rare), and *Madracis johnsoni* (rare). These species constitute only a small proportion of the 17 species recorded from the Lisbon of Alabama. It is known that many of these species are closely controlled by facies and are encountered

only at certain horizons and localities. For example, at the type locality at Souwilpa Creek those species which occur with *Caryophyllia mcglameryae* range only through the lower 10 feet of the Lisbon. This portion of the section is composed principally of glauconitic sands and silts with varying amounts of lime and thin beds of *Ostrea lisbonensis*. Above, the beds are predominantly marly in nature, with some glauconite, and contain no corals except a more robust *Balanophyllia*.

In the Alabama region, *Flabellum cuneiforme* is the only coral which seems to range stratigraphically throughout the Lisbon formation. At Little Stave Creek, Clarke County, this species is extremely abundant in the lower portions of the section, so much so that the term "*Flabellum* bed" is used there. It is associated with a tall slender *Balanophyllia* similar to that from Souwilpa Creek except for more numerous septa. Somewhat higher in the section, *Discotrochus orbignyanus* becomes more common, but is not generally associated with *F. cuneiforme*. The lower portion of the section there is less glauconitic and appears to be composed of finer sediments. In coarser, more calcareous sand, containing an abundant molluscan fauna, as those below the first and third *Ostrea selliformis* beds, corals including *Archohelia gardnerae*, *Endopachys maclurii*, *Turbinolia pharetra*, *Dendrophyllia lisbonensis*, and *Flabellum cuneiforme* are common. This fauna is a precursor of that of the Gosport formation, which contains all of those species listed above. Nowhere in the Little Stave Creek section was the new species collected, or the same general association of corals encountered.

To the west, in eastern Mississippi, the lower Lisbon, or Winona formation, consists of highly glauconitic sands which rapidly weather to limonitic sands. Fresh fossils are difficult to obtain and careful examination of many thousands of molds has failed to yield a single specimen of coral.

Unfortunately, too little is known of the factors involved in the distribution of the simple or ahermatypic corals. This in large part results from the fact that a majority of the fossil genera living today are found in deeper waters, which makes observation of their adaptation to their environment difficult. Studies of the distribution of Indo-Pacific deep-water corals have indicated that substrate is an important factor in the determination of corallum form, and coral assemblage. This is not surprising in view of the extensive literature on reef corals indicating their susceptibility to variations in growth form in response to substrate, current and other conditions. Applied to ahermatypic corals, this information is as yet too incomplete to permit positive detection of ecophenotypes.

LOPHELIA Milne-Edwards and Haime, 1849

LOPHELIA TUBAEFORMIS, n. sp.

Pl. 126, fig. 10–12

Corallum dendroid, bushy (?) formed by long, alternately budding groups of corallites. Because of the nature of budding, coralla are fragile, and are usually preserved as individual corallites, broken from the mother corallite at the point of attachment. Corallites bud from the margin of the calices either alternately or in pairs and retain organic connection to the parent. Corallites are trumpet shaped, long and slender, often somewhat curved. Wall thin, not often over 1 mm. in thickness, with the lower portions of the corallite partially filled by a secondary deposit of stereome. Costae are never prominent, but may extend the length of the corallite, appearing as low, rounded ridges about twice the width of the interspaces. Corallites are circular to oval, depending upon the number of buds developing from the margin. Septa are 22 to 28 in number, arranged in three conspicuous cycles with portions of the fourth cycle present in some calices. Septa of the first cycle are thicker and longer than those of other cycles and extend to the center of the calice where they meet without forming a columella. In several of the calices, four of the first cycle septa are enlarged more than the other two, these being coupled and opposed, with budding corallites developing from between members of the couple. Second cycle septa are somewhat smaller and do not extend to the center of the calice. Septa of the third cycle are short and appear as low ridges on the wall of the corallite. Septa of the fourth cycle are somewhat smaller than those of the third, and are inserted adjacent to third

cycle septa, but not in any apparent order. All septa are straight and lightly granulate laterally. Endotheca is tabular, deep, and not abundant.

MEASUREMENTS IN MM.

	Diameters of calice	Height of corallite	Septa
Holotype			
A.M.N.H. 28030	9.3×6.5	17.8	23
Paratypes			
A.M.N.H. 28031/1	6.8×5.7	20.0	28
A.M.N.H. 28031/2	7.3×5.8		22
A.M.N.H. 28031/3	6.1×5.2	14.7	23
A.M.N.H. 28031/4	5.9	12.2	
A.M.N.H. 28031/5	5.4		

Type specimens.—Holotype, A.M.N.H. 28030; paratype, A.M.N.H. 28031/1–28031/5. Chalcedonized boulder from west bank of the Flint River at Russell or Blue Springs approximately four miles southwest of Bainbridge, Georgia. Collected by D. F. Squires and E. J. Hawkins, July, 1956.

Remarks.—Lophelia has been found as a fossil in only one other instance, *Lophelia parvisepta* (Tenison-Woods), 1880, from the Miocene and Pliocene of New Zealand. Gerth (1921, p. 422) reported but did not describe or figure a specimen of this species from the Miocene of Java. Today, the species is widely distributed in deeper waters of the Atlantic and Mediterranean.

Lophelia tubaeformis differs from the species described as *Scolangia parvisepta* by Tenison-Woods (1880, p. 18, fig. 18) in many respects. Septa in the new species are less numerous, thicker, and do not form the tangle in the center of the calice as the septa of the latter do. Development of a thick peritheca is not so extensive in *L. tubaeformis*.

Recent specimens of *Lophelia*, particularly *L. prolifera* (Pallas) differ in having more septa and corallites of a different shape. Typically, the budding of both *L. prolifera* and *L. tubaeformis* is alternate, with corallites developing first on one side of the mother, then on the other. Individual corallites then grow away from the point of budding. Other differences include the character of the costae and the straight septa of *L. tubaeformis*, as contrasted with the somewhat sinuous septa of *L. prolifera*.

Lophelia californica Durham (1947) is quite similar to the new species in the type of budding, but differs by having, in general, more septa and smaller calices. It also lacks the prominent septa of the first cycle and the straight septa of the new species.

Vaughan (1919, p. 205) considered the cherty boulders of the Flint River to be of middle Oligocene (Rupelian) age. MacNeil (1946, p. 64) stated that materials of Eocene (Ocala), Oligocene and Miocene age are mixed together, stating further that where Ocala and Oligocene faunas are found together, they cannot be differentiated. Recently, Hendry & Yon (mss.) have indicated the presence of boulders of Suwannee age and admit the possibility of Upper Eocene material being present, particularly in northern Florida (see Vernon, 1942, p. 130–133).

The boulder from which *Lophelia tubaeformis* was taken contains large numbers of corals but unfortunately no other identifiable invertebrates have yet been recovered. It is hoped that further preparation will yield some for correlation, particularly since corals have been found in three lithic types of boulders possibly representing two ages. The boulder under consideration has a fauna containing nearly all elements described by Vaughan from that locality. Included are: large masses of *Actinacis* cf. *A. alabamensis* Vaughan, *Stylophora minutissima* Vaughan, *Montastrea bainbridgensis* (Vaughan), *Antiguastrea* cf. *A. celluosa* (Duncan), *Diploastrea* ? sp., and a species of branching *Porites*. Recently many of the species have been recognized in core material from the *Heterostegina* zone of the Gulf Coast, and there is a distinct possibility that many of the species are present in the largely undescribed Tampa limestone fauna. The problem of the age of the fauna of this unusual occurrence is not solved.

A point of some interest is the association of the species with a reef fauna. Vaughan & Wells (1943, p. 215) indicate a depth range for *Lophelia prolifera* of 64 to 1975 meters. The upper portion of this range is just within the lower limit of the active growth of reef corals. Temperature range indicated by Vaughan & Wells (1943, p. 53) for *L. prolifera* indicates that the species prefers waters much cooler than that needed for flourishing growth of reef corals.

The species actually may have had a greater range of tolerance, or may have been growing on the flanks of the reef among reef detritus.

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SIZE, LOBATION, VELATE STRUCTURES, AND ORNAMENTATION IN SOME BEYRICHIID OSTRACODS

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ABSTRACT—Although beyrichiid ostracods of the subfamilies Beyrichiinae and Treposellinae vary greatly in size, lobation, velate structures, and ornamentation, no interrelation of these features can be found. Many beyrichiid ostracods are trilobate, some are bilobate, and a few are unilobate. Lobation includes long ridges, small nodes, and large lobes. Velate structures range from low, narrow ridges to very broad frills. Valves of a few ostracods are smooth, whereas others are ornamented with pustules and tubercles, reticulation, or small striae.

Velate structures, however, seem to have progressively encroached onto the brood pouch in female valves. No Lower Silurian beyrichiids have velate structure on the pouch, some Middle Silurian species have part of the frill on the pouch, and an Upper Silurian and a Lower Devonian species have the frill continuous across the pouch. This generalized trend has many exceptions, and it may not have been very significant.

From the species studied, we conclude that size, lobation, velate structures, and ornamentation have no suprageneric significance and that a brood pouch in the female dimorph is the only characteristic shared by beyrichiid ostracods.

Lastly, it is pointed out that *Treposella lyoni* is trilobate and has a distinct semisulcus along the entire juncture of the brood pouch and the lateral surface.

INTRODUCTION

ALTHOUGH the ostracods in the family Beyrichiidae are generally known to have great variations in size and shape, a summary of the characters in selected species emphasizes the extent of such variation. We have not attempted to describe the size, lobation, velate structure, and ornamentation in all beyrichiid ostracods; frankly, we believe that, in many species, specimens have not been found sufficiently well-preserved to show these characters. For several species type specimens were examined, and for others new specimens were obtained. Many of the old descriptions are seriously lacking in details, and are written in ambigous terminology. Furthermore, the old illustrations are so poor that little can be gained from their study. The species described here, we think, are representative of beyrichiin and treposellin ostracods. All are based on excellently preserved adult males and females.

The Beyrichiidae has been revised several times since its creation. Ulrich & Bassler (1908) regarded the family as a large taxon of lobate, straight-hinged Paleozoic ostracods. Of their genera, only *Beyrichia*, *Kloedenia*, and *Treposella* have been retained in the Beyrichiidae and the others are distributed in the Drepanellidae, Eurychilinidae, Hollinidae, Kloedenellidae, and Tetradellidae. In 1923 (p. 310–312) Ulrich & Bassler sharply restricted the family Beyrichiidae, which they defined as: "Valves trilobate or quadrilobate, deeply sulcated; brood pouch when present, very prominent, subglobular or egg-shaped, on the ventral slope." Bassler & Kellett (1934, p. 26–29), on the other hand, expanded the family to include many ostracods lacking pouches. Swartz (1936, p. 547–549) contributed greatly to our present classification by emending the Beyrichiidae and placing many genera into new families. In 1953 (p. 264) Henningsmoen revised the classification of Paleozoic straight-hinged ostracods and further limited the Beyrichiidae. In his latest work on the family (1955, p. 241) he gave the following diagnosis: "Dimorphic straight-hinged ostracods in which one of the dimorphs of each species has a pair of pouches, one in each valve, situated anteriorly to posteroventrally. The pouches open into the main cavity of the carapace. Non- to trisulcate. S1 more persistent than S2.

Velate structure usually present as a ridge or frill." [We believe the diagnosis contains a misprint, and that Henningsmoen intended to repeat part of his previous diagnosis (1954, p. 20); "S1 more persistent than S3."]

The ostracods studied in this investigation belong to two of the four subfamilies recognized by Henningsmoen (1955, p. 241), the Beyrichiinae and the Treposellinae. These ostracods have brood pouches more protuberant and distinct than those in the other two subfamilies, the Zygobolbinae and the Kloedeniinae. They include the genera *Beyrichia*, *Eobeyrichia*, *Mitrobeyrichia*, *Neobeyrichia*, *Nodibeyrichia*, *Velibeyrichia*, *Apatobolbina*, *Bolbibollia*, *Dibolbina*, *Bolbiprimitia*, *Hibbardia*, *Mesomphalus*, *Phlyctiscapha*, and *Treposella*. We have raised the subgenera of *Beyrichia* defined by Henningsmoen (1954, p. 22–27) to generic rank, without regard for the possibility that *B. tuberculata* (Klöden) is the type species of *Beyrichia*, as suggested by Kesling & Wagner (1956, p. 39–42).

The most recent hypothesis on the origin of the beyrichiids is by Kesling (1957), who concluded that they descended from the piretellids and that the female brood pouch originated when a strongly convex part of the frill fused with the contact margin. He studied several of the specimens shown in plates 127–130, but he illustrated his paper with drawings of reconstructed valves.

We are sincerely grateful to the workers who made this study possible. Dr. Gunnar Henningsmoen of the Paleontologisk Museum, Oslo, Norway, sent specimens of *Mitrobeyrichia jonesii* (Boll) and *Craspedobolbina armata* Henningsmoen and loaned type specimens of *Beyrichia kiaeri* Henningsmoen. Dr. Remington Kellogg, Dr. A. R. Loeblich, Jr., and Dr. I. G. Sohn loaned type specimens from the National Museum. Dr. R. S. Bassler kindly supplied washings of the Jeffersonville limestone from the Falls of the Ohio, from which the illustrated specimens of *Treposella lyoni* were obtained.

The specimens we investigated are deposited in the Museum of Paleontology of the University of Michigan (UMMP), the United States National Museum (USNM), and the Paleontologisk Museum at Oslo (PMO).

TERMINOLOGY

Most of our terms are found in Kesling (1951), Henningsmoen (1954), and Kesling & Wagner (1956, p. 46–47, text-fig. 3). Additional terms are needed for the relationship of the velate structure to the brood pouch in female valves. We refer to the velate structure as *interrupted* if it is separated into two parts, neither of which joins the brood pouch, as *encroaching* if the two parts extend onto the brood pouch but do not meet, and as *complete* if it crosses the brood pouch without interruption.

ABBREVIATED DESCRIPTIONS

Family BEYRICHIIDAE Jones 1855

We do not know with certainty to whom the authorship of the family should be credited. The author of a family, according to current interpretation, is he who first applies to a suprageneric taxon a name based on a genus in the taxon, using the stem of the generic name. In 1855, Prof. T. Rupert Jones published two articles in the Annals and Magazine of Natural History. In each article he referred to the "Beyrichiae" (first on p. 81), and in each he divided the "Beyrichiae" into three "groups," the Simplices, Corrugatae, and Jugosae. We have considered the following: (1) Jones included only species of *Beyrichia* in his Beyrichiae, (2) he placed these species (1855*a*, p. 85) in the family "Limnadiadae?", and (3) he did not state the rank of his "Beyrichiae." The question, of course, is what did Prof. Jones intend by his term "Beyrichiae"? Did he, with the taxonomic abandon of his day, mean species of the genus *Beyrichia?* Or did he mean a suprageneric category including, at that time, only the one genus, *Beyrichia?* It is clear that he did not use Beyrichiae as a family, because he placed all species of his Beyrichiae (listed in a table, 1855*b*, p. 175) in the family Limnadiadae?, but this does not exclude the possibility that he meant Beyrichiae to be a suprageneric (albeit less than familial) taxon. In brief, he may have had in mind "ostracods of the *Beyrichia* kind" instead of "species of *Beyrichia*." There is a precedent for considering Jones to be the author of the family. In 1876, in his *Paleontology, Fossil corals* published as Mich. Geol. Survey, v. 3, pt. 2, Carl Ludwig

Rominger used the heading "Columnariae" and on the next line "Consisting of the single genus *Columnaria*." Rominger is now regarded as the author of the suborder Columnariina. We have tentatively given authorship of the Beyrichiidae to Jones, as indicated in the heading.

Matthew is considered to be the author of the family by Martinsson (1956, p. 18). Matthew, (1886, p. 63) used the heading" Beyrichinae." Note his spelling. In the following paragraphs he discussed the classification of Jones in 1855. The genera and species which Matthew described, however, were Middle Cambrian Archaeostraca and not beyrichiid ostracods. Inasmuch as Matthew's only usage of "Beyrichinae" in any sense of a suprageneric category including beyrichiid ostracods was his review of Jones' contribution in 1855, we would not be justified in awarding the authorship to Matthew in place of Jones.

In 1894 (p. 630–632, 657) Ulrich used the term Beyrichiidae definitely in the sense of a family. On page 632 he listed the genera which he thought should be included in the "Family Beyrichiidae." It may be pointed out that the only genus in his list that is still retained in the family is *Beyrichia*.

Genus APATOBOLBINA Ulrich & Bassler 1923

APATOBOLBINA sp.

Pl. 129, fig. 8–11

Lobation.—Unilobate. Prominent subovate pouch in female.

Extralobate area.—Indistinct or none.

Velate structure.—In the male, a frill, distally striate, from near the anterior corner to posteroventral region. In the female, encroaching a short distance onto front and rear parts of the brood pouch.

Ornamentation.—Lateral surface mostly smooth, a few scattered low tubercles. Lateral part of brood pouch striate, ventral part finely striate.

Genus BEYRICHIA McCoy 1846

BEYRICHIA KIAERI Henningsmoen 1954

Lobation.—Trilobate. In the male, L1 an elongate, curved lobe ventrally separated from L2 by a low saddle representing the ventral extension of S1; L2 a prominent node ventrally connected to L3 by a low ridge, which extends well below the ventral end of L1; L3 a full lobe tapering anteroventrally and joined by a U-shaped ridge to L2. S1 a narrow, curved sulcus, shallow in its ventral part; S2 rather deep, reaching below the ventral end of L2. In the female, a large bulbous pouch in the anteroventral region of each valve, separated by a shallow groove or semisulcus from the three lobes; L1 and L2 not as long as in the male; and L3 not connected to L2 ventrally.

Extralobate area.—Narrow around L3, moderately wide along the front edge of L1, and very wide below L1 and in front of the ridge yoking L2 to L3.

Velate structure.—In the male, short spines posteroventrally and long, discrete spines anteroventrally. In the female, short spines behind the brood pouch; no part of the velate structure encroaching onto the brood pouch.

Ornamentation.—Scattered low tubercles on the lobes and side of the pouch. Ventral part of pouch longitudinally striate. Sulci and extralobate area smooth or finely granular.

Remarks.—Martinsson (1956, pl. 2, fig. 5) shows that the ventral part of the pouch in *Beyrichia dactyloscopia* Martinsson is also striate. We have not seen female specimens of *Beyrichia kloedeni* McCoy, *B. nodulosa* Boll, *B. spinigera* Boll, or *B. verrucosa* Kolmodin. Perhaps, the combination of tuberculate sides and striate venter on the pouch will prove to be a generic character.

Genus BOLBIBOLLIA Ulrich & Bassler 1923

BOLBIBOLLIA LABROSA Ulrich & Bassler 1923

Pl. 130, fig. 9,10

Lobation.—Restricted to a small U-shaped ridge in the middle of the lateral surface. Interpreted as bilobate. In the female, a large subovate pouch, not as strongly convex as in most beyrichiid females.

Extralobate area.—Including all of the lateral surface except the U-shaped ridge.

Velate structure.—In the male, a ridge from the anterior to posterior regions, not extending to either corner. In the female, interrupted, but with each half extending under the edge of the pouch.

Ornamentation.—All parts smooth.

Genus BOLBIPRIMITIA Kay 1940
BOLBIPRIMITIA FISSURELLA (Ulrich & Bassler) 1923

Lobation.—Bilobate. In the male, lateral surface evenly convex around long narrow S2, extending from hinge line about two-thirds of the distance to the frill. In the female, a low elongate pouch, posterodorsally nearly confluent with the lateral surface.

Extralobate area.—None.

Velate structure.—In the male, a wide ridge from corner to corner. In the female, extending under the edges of the pouch, but interrupted.

Ornamentation.—Lobate area and most of brood pouch coarsely reticulate. Anterior and anteroventral parts of brood pouch smooth.

Genus "CHILOBOLBINA" Ulrich & Bassler 1923

Kesling (1957) has noted that the Silurian species assigned to *Chilobolbina* by Ulrich & Bassler (1923) are beyrichiids, and are not congeneric with the type species, *C. dentifera* (Bonnema). A new genus will be proposed later for the Silurian beyrichiids presently called "*Chilobolbina.*"

"CHILOBOLBINA" sp.
Pl. 127, fig. 10–14

Lobation.—Bilobate. Lateral surface evenly convex except for small pit near the middle, which is interpreted as S2. Small longitudinal groove in the posterior half of each valve. Subovate brood pouch in the female.

Extralobate area.—None.

Velate structure.—In the male, a very broad frill from corner, distally striate and proximally covered with more or less concentric rows of rectangular papillae. In the female, encroaching onto the brood pouch.

Ornamentation.—Lateral surface finely reticulate, except for smooth areas in the corners and around the central pit. Side of brood pouch finely reticulate, ventral part coarsely reticulate.

Genus CRASPEDOBOLBINA Kummerow 1924

There is no longer any specimen available of the type species, *C. dietrichi* Kummerow, so it is impossible to determine if the genus is a beyrichiid, in which the female valves have brood pouches, or a piretellid, in which the females have false pouches formed by a strongly convex part of the frill. Until study of *C. dietrichi* can be made, we will tentatively regard this genus as a beyrichiid.

CRASPEDOBOLBINA ARMATA
Henningsmoen 1954
Pl. 129, fig. 1–7

Lobation.—Trilobate. All lobes joined to a ventral lobe. L1 a low lobe, L2 a node, and L3 a large lobe. S1 shallow, indistinct; S2 deep, particularly in its ventral part. The brood pouch in the female is not sharply set off from the lateral surface by a groove or semisulcus, as in other beyrichiid species; therefore, we are uncertain about the subfamilial assignment of *C. armata.* It may be a kloedeniid.

Extralobate area.—None, or possibly limited to small anterodorsal and posterodorsal areas.

Velate structure.—In the male, two types are said to occur (Henningsmoen, 1954, p. 47), one from anterior corner to posterior corner and the other from the anterior corner to the posteroventral region. Male velate structure a wide ridge. In the female, the posterior part of the ridge confluent with the rear end of the brood pouch, but the anterior part discrete.

Ornamentation.—Most of the lateral surface and the side of the brood pouch irregularly and finely striate, with a few scattered tubercles on L3 and the ventral lobe. Ventral part of brood pouch regularly and coarsely striate. A large spine in the posterior part of the brood pouch.

Genus DIBOLBINA Ulrich & Bassler 1923
DIBOLBINA STEUSLOFFI (Krause) 1891
Pl. 127, fig. 15–21

Lobation.—Trilobate. In the male, L1 a full lobe; L2 an elongate lobe from hinge line to frill; and L3 a full lobe. S1 and S2 long and narrow, from hinge line to frill. In the female, a subglobular brood pouch in the anteroventral region, separated from L1 and L2 by a semisulcus.

Extralobate area.—Only a small crescentic

area behind L3 may possibly be called extralobate.

Velate structure.—In the male, a very broad striate frill extending from corner to corner, proximally bearing a narrow ridge in its ventral part. In the female, complete; the proximal ridge found only in the posterior part, joined to the brood pouch; a corresponding proximal ridge under the frill curving around all of the brood pouch (pl. 127, fig. 18,20,21).

Ornamentation.—Lobes and brood pouch smooth.

Genus HIBBARDIA Kesling 1953
HIBBARDIA LACRIMOSA (Swartz & Oriel) 1948
Pl. 127, fig. 22–26

Lobation.—Bilobate. In the male, S2 shallow in dorsal part, terminating in a deep central pit; rest of lateral surface convex, the lobes confluent with a large ventral lobe. In the female, an elongate brood pouch in the posteroventral and ventral parts of each valve, posteriorly nearly confluent with the lateral surface; very similar to the brood pouch in *Phlyctiscapha*.

Extralobate area.—None.

Velate structure.—In the male, a narrow frill from corner to corner. In the female complete below the brood pouch, but at the front end of the pouch split longitudinally, the inner part continuous and the outer interrupted, the two ends turned outward onto the pouch.

Ornamentation.—Lateral surface reticulate, except for anterior corner area, which is smooth. Most of brood pouch reticulate like the lateral surface, but anteroventral part finely reticulate.

Genus MESOMPHALUS Ulrich & Bassler 1913
MESOMPHALUS HARTLEYI Ulrich & Bassler 1913
Pl. 130, fig. 11–15

Lobation.—Trilobate. In the male, L1 not strongly convex, low, ventrally confluent with a long ventral lobe; L2 a low node, ventrally joined to a curved ridge yoking it to L3; and L3 large, not strongly convex, ventrally separated from the ventral lobe by a curved longitudinal groove. In the female, a very elongate brood pouch on the ventral lobe.

Extralobate area.—None, or very little.

Velate structure.—In the male a thick ridge from corner to corner. In the female, apparently complete below the brood pouch; in one of the type specimens, USNM 53304, carapace crushed and velate ridge broken in each valve.

Ornamentation.—Effaced in many specimens. Lateral surface and side of brood pouch covered with papillae of two sizes, the smaller more numerous. Ornamentation indistinct on the ventral part of the brood pouch, but seems to be like that on the side.

Remarks.—The original figures of *M. hartleyi* published by Ulrich & Bassler (1913, pl. 95, fig. 22–24; pl. 96, fig. 1–3) are drawings, which are inaccurate in several details, particularly lobation, as already pointed out by Swartz & Whitmore (1956, p. 1076–1077). The type specimens are illustrated here in pl. 130, fig. 11–15.

Genus NEOBEYRICHIA Henningsmoen 1954

The species in *Neobeyrichia* vary greatly in lobation, extralobate area, and ornamentation. We selected four species that appear to be typical of extremes in these characters.

NEOBEYRICHIA BUCHIANA (Jones) 1855
Pl. 129, fig. 15–18

Lobation.—Trilobate. Lobes present as long ridges. In the male, L1 slightly curved, distinctly separate from L2; L2 and L3 joined as a large U-shaped ridge. S1 a long smooth channel; S2 broad, its bottom rather flat. In the female, a large subglobular pouch in the anteroventral region; L1 and L2 elongate nodes; and L3 terminating behind the brood pouch, not joined to L2.

Extralobate area.—Broad, from corner to corner, separated from the wide marginal surface by a distinct bend.

Velate structure.—In the male a low ridge from the anterior to the posterior region on the marginal surface, nearly parallel to the free edge and to a submarginal ridge. In the female, interrupted by the brood pouch.

Ornamentation.—Low, large pustules scattered on the lobes and along the bend. Some

specimens have pustules only on L3. Sulci, extralobate area, and all of pouch smooth.

NEOBEYRICHIA KOCHII (Boll) 1862
Pl. 127, fig. 8–9; pl. 128, fig. 3–4

Lobation.—Trilobate. In the male, L1 a long full lobe; L2 a long lobe, almost confluent with L3; and L3 a large lobe with one oblique groove in its ventral half, separated from L2 by a shallow saddle. S1 long, from hinge line to frill; S2 wider than S1, with a distinct elongate tubercle in its dorsal part at the hinge line. In the female, a subovate brood pouch; L1 and L2 smaller than in male, separated from brood pouch by a shallow groove.

Extralobate area.—Very small, limited to crescentic areas in front of L1 and behind L3.

Velate structure.—In the male, a narrow striate frill in the ventral part, tapering anteriorly and posteriorly into low ridges extending to the corners. In the female, interrupted.

Ornamentation.—Low pustules on L3; L1, L2, and all parts of brood pouch smooth.

Remarks.—Each valve has a wide marginal surface, with a row of submarginal closely-spaced papillae. In the female this row is continuous below the brood pouch, corresponding to the continuous submarginal structures in many other beyrichiid females.

NEOBEYRICHIA MACCOYIANA SULCATA (Reuter)
Pl. 128, fig. 1–2; pl. 129, fig. 12–14

Lobation.—Trilobate. In the male, L1 a long lobe, ventrally joined to L3 by a narrow ridge below L2; L2 an elongate large node, separated from the junction of L1 and L3 by a shallow saddle; and L3 a large lobe, crossed by a long curved groove subparallel to its dorsal and posterior borders. In the female, a large subovate brood pouch in the anteroventral part of each valve, posteroventrally nearly confluent with the marginal surface; L1 and L2 much smaller than in the male, separated from the brood pouch by a groove; and L3 not joined to L1.

Extralobate area.—Small, except below the junction of L1 and L3.

Velate structure.—Different from that in any other beyrichiid. In the male, continuous from corner to corner; a velate ridge in the anterior and posterior regions; a thick frill in the ventral region, proximally broadly striate and distally finely striate; in the anteroventral region the frill flares sharply outward before it joins the anterior velate ridge. In the female, a velate ridge extending from the posterior corner to the front of the brood pouch, there terminating distal to a second velate ridge, which extends parallel to the free border from the anterodorsal end of the pouch to the anterior corner; this in

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EXPLANATION OF PLATE 127
All figures ×25

FIG. *1–4*—*Treposella lyoni* (Ulrich). *1–3*, dorsal, lateral, and ventral views of female left valve, topotype, UMMP 30511; this is the best specimen of a female valve that has been found. *4*, lateral view of incomplete male right valve, topotype, UMMP 30513.

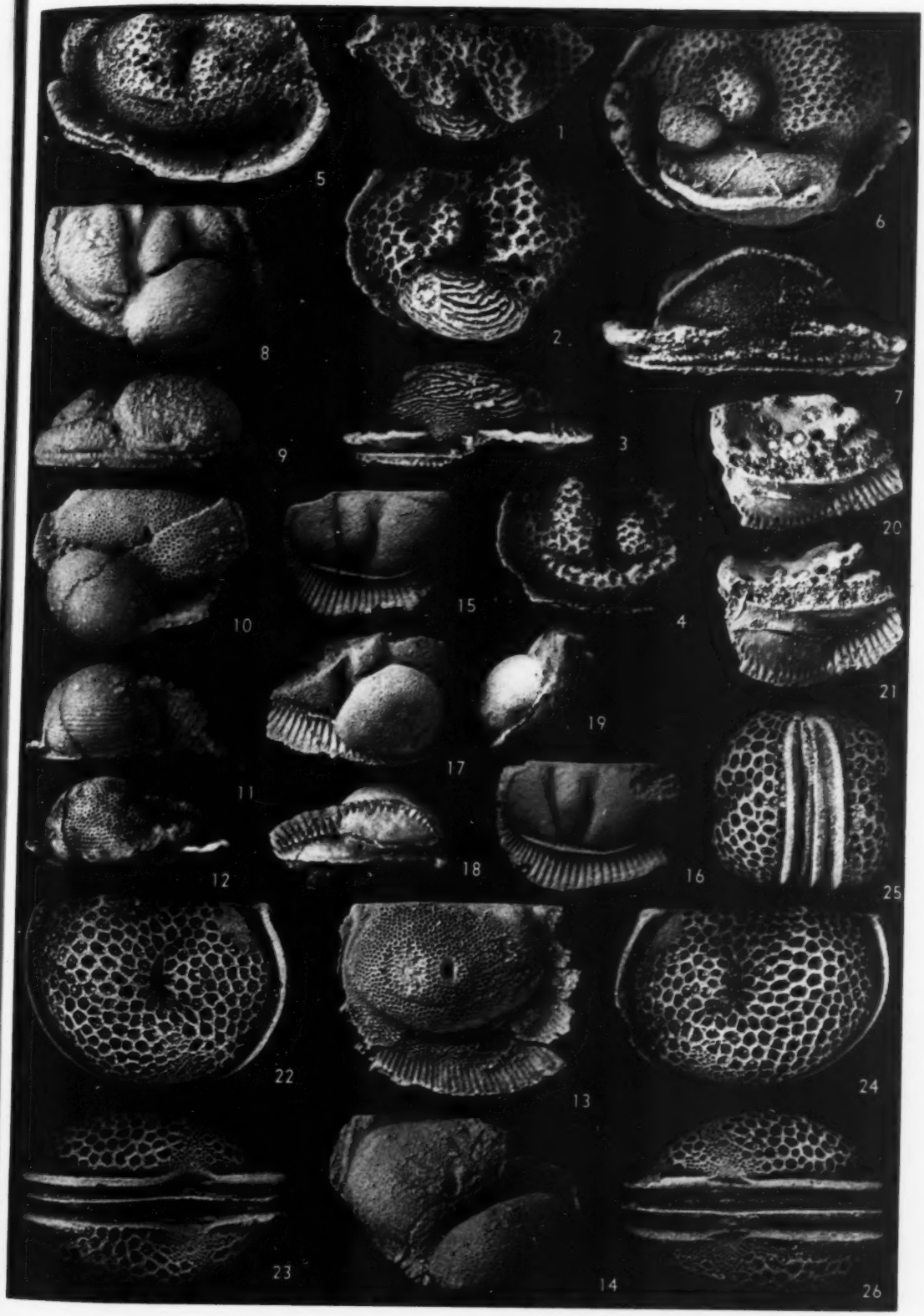
5–7—*Treposella stellata* Kesling. *5*, lateral view of male right valve, allotype, UMMP 30502, *6,7*, lateral and ventral views of female left valve, holotype, UMMP 30501; the protuberance on the anterior end of the pouch is assumed to be foreign.

8–9—*Neobeyrichia kochii* (Boll). Lateral and ventral views of a female right valve, UMMP 33767.

10–14—"*Chilobolbina*" sp. *10–12*, lateral and two ventral views of female left valve, UMMP 33752; fig. *12* photographed without coating of ammonium chloride to show the ornamentation more clearly. *13*, lateral view of male right valve. UMMP 33748. *14*, lateral view of incomplete female right valve, UMMP 33751. All specimens from the Middle Silurian Schoolcraft formation of Michigan.

15–21—*Dibolbina steusloffi* (Krause). *15,16*, lateral views of two male left valves, UMMP 32688*b* and 32688*a*. *17–21*, lateral, ventral, anterior, interior, and inclined interior views of an incomplete female right valve, UMMP 32690, showing the complete frill.

22–26—*Hibbardia lacrimosa* (Swartz & Oriel). *22,23*, right lateral and ventral views of a female carapace. *24–26*, left lateral, posterior, and ventral views of a female carapace. Both specimens were destroyed in preparation of polished surfaces.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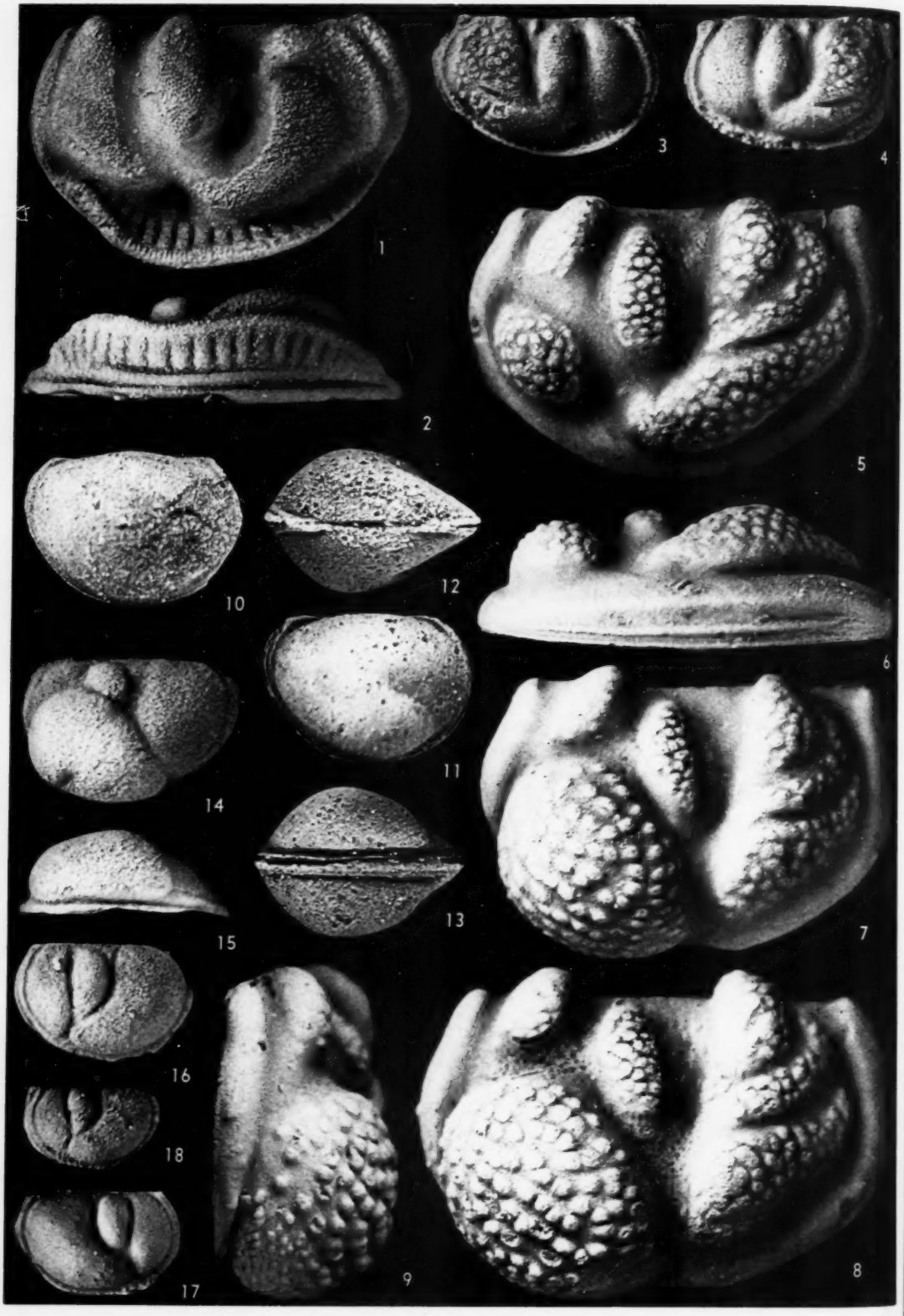
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terruption of the velate structure apparently corresponds to the sharply flared part of the frill in the male.

Ornamentation.—Lobes covered with a very fine reticulation. Ventral part of the brood pouch more coarsely reticulate.

NEOBEYRICHIA SALTERIANA
(Jones) 1855
Pl. 128, fig. 14–18

Lobation.—Trilobate. Lobes very large, covering almost all of lateral surface. In the male, L1 long; L2 an elongate lobe; and L3 very large, anteroventrally extending below all of L2. S1 long, very narrow, extending from hinge line to velate structure; S2 long, curved, very narrow, confluent with S1 anteroventral to L2. In the female, S1 and S2 short, terminated by the large subovate brood pouch, which extends dorsally far up on the valve, its anterodorsal edge separated from the hinge line by only about one-fourth of the height.

Extralobate area.—None. Lobes are bordered by the velate structure.

Velate structure.—In the male, a ridge very low in the anterodorsal and posterodorsal regions; wider, faintly striate, and rather sharp-edged in the ventral region. In the female, a low ridge interrupted by the brood pouch.

Ornamentation.—Lobes, sulci, and all of brood pouch smooth.

Genus NODIBEYRICHIA Henningsmoen
1954

NODIBEYRICHIA TUBERCULATA
(Klöden) 1834
Pl. 128, fig. 5–9;, pl. 129, fig. 19;
pl. 130, fig. 1–2

Lobation.—Trilobate. In the male, L1 is two discrete nodes; L2 an elongate node; and L3 large, roughly D-shaped, crossed obliquely by two grooves, ventrally extending forward below L2. S1 and S2 distinct sulci, confluent below L2 and extending to the ventral edge of the lobate area. In the female, a large subovate brood pouch in the anteroventral region; L1 a discrete node in the anterodorsal area; L2 with its axis more inclined than that of the male; and L3 terminating anteroventrally rather abruptly, separated from the brood pouch by part of S2.

Extralobate area.—Broad, extending from corner to corner, separated from the wide marginal surface by a distinct bend.

Velate structure.—In the male, a low ridge on the marginal surface extending from the anterior to the posterior region, subparallel to the free edge, lying between the bend and a submarginal ridge. In the female, a low ridge interrupted by the brood pouch.

Ornamentation.—Lobes covered with large pustules and a few tubercles. Sulci and extralobate area smooth, except for a few scattered tubercles along the bend in some specimens. Side of brood pouch ornamented like the lobes, ventral part covered with small tubercles.

Remarks.—*Nodibeyrichia tuberculata* closely resembles *N. gedanensis* (Kiesow), *N. noetlingi* (Reuter), *N. bronni* (Reuter), *N. baueri* (Reuter), *N. tuberculata gibbosa* (Reuter), *N. tuberculata bigibbosa* (Reuter), *N. tuberculato-buchiana* (Reuter), *N. buchianotuberculata* (Reuter), and *N. tuberculato-kochiana* (Reuter), particularly in lobation, extralobate area, and velate ridge. Ornamentation varies within the genus, and it is

EXPLANATION OF PLATE 128
All figures ×25

FIG. *1–2—Neobeyrichia maccoyiana sulcata* (Reuter). Lateral and ventral views of a male left valve, UMMP 33759.

3–4—Neobeyrichia kochii (Boll). Lateral views of a male right valve and a male left valve, UMMP 33765 and 33764.

5–9—Nodibeyrichia tuberculata (Klöden). *5,6*, lateral and ventral views of a male left valve, UMMP 32079; the velate ridge is near and parallel to the free edge and can be seen only in ventral view. *7*, lateral view of female left valve, UMMP, 32103. *8,9*, lateral and anterior views of female left valve, UMMP 32083.

10–13—Phlyctiscapha rockportensis Kesling. *10*, right lateral view of male carapace, allotype, UMMP 29610. *11–13*, dorsal, right lateral, and ventral views of female carapace, holotype, UMMP 29603.

14–18—Neobeyrichia salteriana (Jones). *14,15*, lateral and ventral views of female carapace, UMMP 30510. *16–18*, lateral views of three immature male valves, left, right, and left, UMMP 30517, 33746, and 33754.

TABLE 1.—CHARACTERISTICS OF CERTAIN BEYRICHIID OSTRACODS

Species	Age	Length female (mm.)	Lobation	L1	L2	L3
Bolbibollia labrosa Ulrich & Bassler	M. Sil.	0.67	bilobate	small U-shaped ridge		
Bolbiprimitia fissurella (Ulrich & Bassler)	U. Sil.	1.12	bilobate	lobe		lobe
Dibolbina steusloffi (Krause)	U. Sil.	1.24	trilobate	full lobe	long lobe	full lobe
Neobeyrichia salteriana (Jones)	U. Sil.	1.40	trilobate	full lobe	long lobe	full lobe
Velibeyrichia fittsi (Roth)	L. Dev.	1.50	trilobate	confluent* full lobe	node	confluent full lobe
Neobeyrichia kochii (Boll)	U. Sil.	1.54	trilobate	full lobe	long lobe	full lobe
"*Chilobolbina*" sp.	M. Sil.	1.55	bilobate	full lobe around pit		
Apatobolbina sp.	M. Sil.	1.65	unilobate	evenly convex		
Treposella lyoni (Ulrich)	M. Dev.	1.65	trilobate	confluent full lobe	node	confluent full lobe
Craspedobolbina armata Henningsmoen	L. Sil.	1.70	trilobate	confluent full lobe	node	confluent full lobe
Phlyctiscapha apleta Kesling	M. Dev.	1.74	unilobate	evenly convex		
Hibbardia lacrimosa (Swartz & Oriel)	M. Dev.	1.80	bilobate	confluent full lobe		confluent full lobe
Mesomphalus hartleyi Ulrich & Bassler	L. Dev.	1.80	trilobate	confluent low lobe	node	low full lobe
Treposella stellata Kesling	M. Dev.	1.98	trilobate	confluent full lobe	node	confluent full lobe
Neobeyrichia maccoyiana sulcata (Reuter)	U. Sil.	2.15	trilobate	long ridge	node	full, 1 groove
Neobeyrichia buchiana (Jones)	U. Sil.	2.40	trilobate	long ridge	long ridge	confluent ridge
Beyrichia kiaeri Henningsmoen	M.-U. Sil.	2.50	trilobate	confluent full lobe	node	confluent full lobe
Nodibeyrichia tuberculata (Klöden)	U. Sil.	2.73	trilobate	2 nodes	long node	full, 2 grooves

* "Confluent" means that the lobe in the male is ventrally confluent with another lobe.

TABLE 1—(*Continued*)

S1	S2	Velate structure	Velate str. to brood pouch rel.†	Ornamentation			Specimens
				Lobes	Brood pouch		
					lateral	ventral‡	
	short sulcus	ridge	below pouch	smooth	smooth	smooth	USNM 82406
	long, narrow	ridge	incomplete below pouch	coarsely reticulate	coarsely reticulate	smooth	UMMP 33747
long, narrow	long, narrow	wide frill	complete	smooth	smooth	smooth	UMMP 32690 32688
long, narrow	long, narrow	ridge	interrupted	smooth	smooth	smooth	UMMP 30510 30517
sulcus	broad sulcus	wide frill	complete	reticulate	reticulate	coarsely reticulate	USNM 80655
long sulcus	sulcus	narrow frill	interrupted	L3 a few pustules	smooth	smooth	UMMP 33767 33764
	pit	wide frill	encroaching	reticulate	reticulate	coarsely reticulate	UMMP 33751 33748
		frill	encroaching	smooth	coarsely striate	finely striate	UMMP 30492 30494
shallow	sulcus & pit	frill	encroaching	reticulate	coarsely striate	finely striate	UMMP 30511 30513
shallow	deep sulcus	ridge	interrupted	finely striate	finely striate	coarsely striate	UMMP 33756 33753
		low ridge	below pouch	smooth	smooth	smooth	UMMP 30482 30490
	sulcus & pit	narrow frill	below pouch	reticulate	reticulate	finely reticulate	UMMP 28455
very faint	rather short	thick ridge	complete?	papillae, 2 sizes	papillae, 2 sizes	?	USNM 53304
shallow	sulcus	wide frill	encroaching	reticulate	smooth	smooth	UMMP 30501 30502
long sulcus	broad sulcus	frill	across, but interrupted	finely reticulate	finely reticulate	coarsely reticulate	UMMP 33762 33759
long sulcus	broad sulcus	low ridge	interrupted	few pustules	smooth	smooth	UMMP 30516 33741
narrow sulcus	long sulcus	spines	interrupted	scattered tubercles	scattered tubercles	striate	PMO 46559*b* 66449*a*
long sulcus	broad sulcus	low ridge	interrupted	pustules, tubercles	pustules, tubercles	small tubercles	UMMP 32100 32079

† The relation of velate structure to broad pouch is described as "interrupted" if the frill does not extend onto the pouch, as "encroaching" if the frill extends onto the pouch but does not cross it, and as "complete" if the frill crosses the pouch without interruption.

‡ The ventral side of the brood pouch in the Beyrichiinae and the anterior part of the pouch in the Treposellinae have a different kind of ornamentation from that on the side of the pouch in many species.

now known whether the other species have smaller ornament on the ventral part of the brood pouch.

Genus PHLYCTISCAPHA Kesling 1953
PHLYCTISCAPHA ROCKPORTENSIS
Kesling 1953
Pl. 128, fig. 10–13

Lobation.—Unilobate. Pouch in the female posteriorly confluent with the lateral surface of the valve.

Extralobate area.—None, or possibly limited to corner areas.

Velate structure.—Very low, indistinct ridge complete below pouch.

Ornamentation.—Smooth.

PHLYCTISCAPHA APLETA Kesling 1954

All features like those in *P. rockportensis* Kesling except for size and proportions.

Genus TREPOSELLA Ulrich & Bassler 1908
TREPOSELLA LYONI (Ulrich) 1891
Pl. 127, fig. 1–4; pl. 130, fig. 8

Lobation.—Trilobate. In the male, L1 a full lobe, ventrally confluent with the ventral lobe; L2 a node well below the hinge line; and L3 a large lobe, projecting above the hine line, ventrally nearly connected to the ventral lobe but separated by a shallow groove. S1 shallow, connected dorsally and ventrally with S2; S2 broad, with a deep central pit. In the female, a subovate brood pouch on the ventral lobe.

Extralobate area.—None apparent.

Velate structure.—In the male, a frill from corner to corner, smooth. In the female, encroaching onto both ends of the brood pouch.

Ornamentation.—All of lateral surface reticulate, with small projections inward from the crests, giving the interstices a stellate shape. Brood pouch irregularly striate, coarsely on the side and finely on the ventral part.

Remarks.—Each valve has a smooth submarginal ridge and a row of discrete but closely-spaced marginal papillae.

TREPOSELLA STELLATA Kesling 1955
Pl. 127, fig. 5–7

Lobation.—Like that of *T. lyoni*, but with two grooves in the posterior part, one through the middle of L3 and one between L3 and the ventral lobe. Brood pouch with the broad, slightly convex dorsal and ventral halves meeting in a distal ridge.

Extralobate area.—None apparent.

Velate structure.—In the male, a wide frill from corner to corner, striate, faintly in the posterior part and distinctly in the rest. In the female, both halves encroaching on the ventral surface of the pouch.

Ornamentation.—All of lateral surface reticulate, with stellate interstices like those in *T. lyoni*. Brood pouch smooth.

Remarks.—A smooth submarginal ridge, and a row of discrete papillae between the ridge and the frill, both continuous across the area proximal to the brood pouch.

EXPLANATION OF PLATE 129
All figures ×25

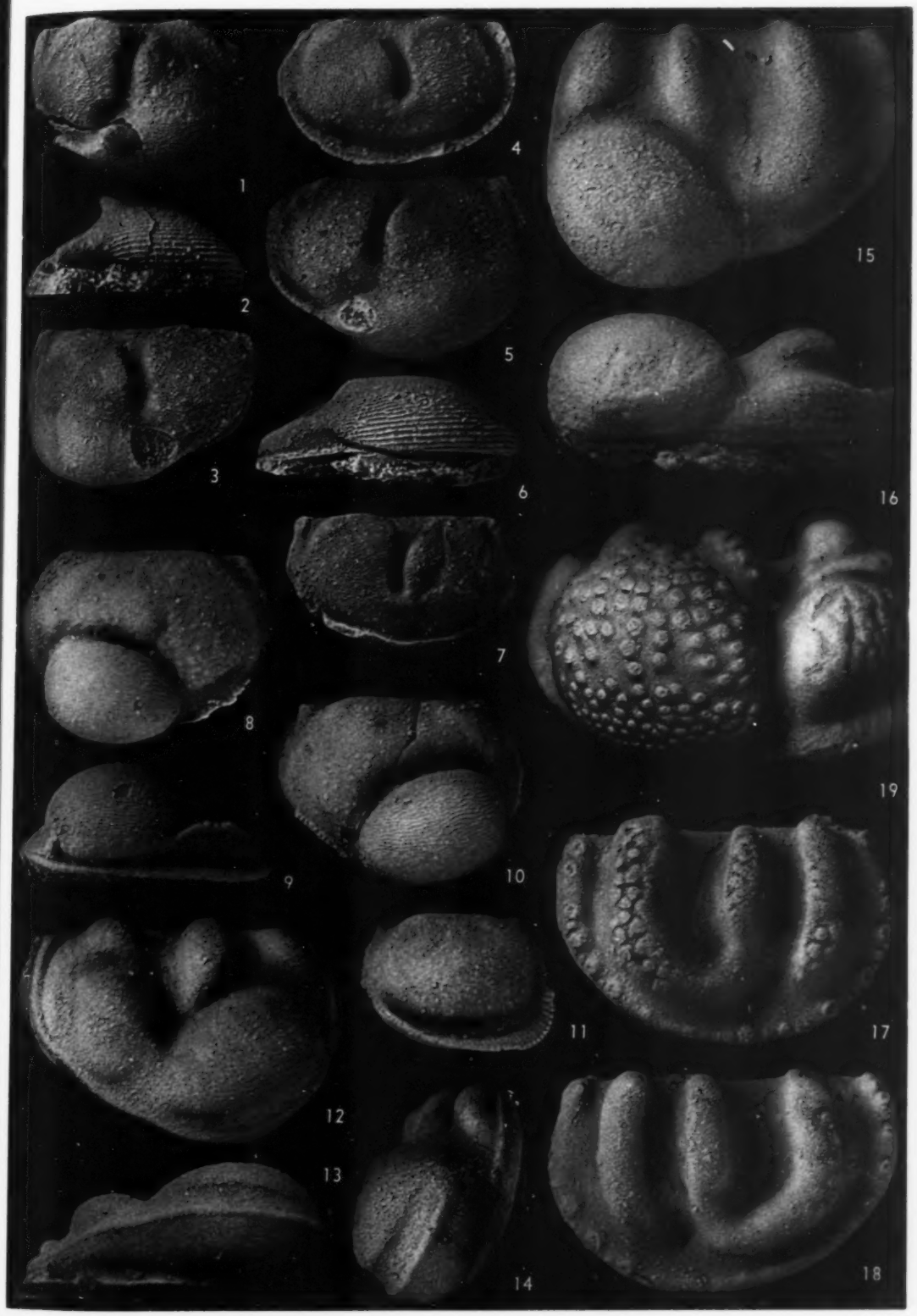
FIG. *1–7—Craspedobolbina armata* Henningsmoen. *1,2,5,6*, lateral and ventral views of two female right valves, UMMP 33756 and 33758; spur broken from the latter. *3*, lateral view of female left valve with spur broken from rear end of brood pouch, UMMP 33757. *4*, lateral view of male left valve with complete velate ridge, UMMP 33753. *7*, lateral view of male right valve with restricted velate ridge, UMMP 33755.

8–11—Apatobolbina sp. 8–9, lateral and ventral views of female left valve, UMMP 30492. *10*, lateral view of female right valve, UMMP 30495. *11*, lateral view of immature right valve, UMMP 30494. All specimens from the Middle Silurian Schoolcraft formation in Michigan.

12–14—Neobeyrichia maccoyiana sulcata (Reuter). Lateral, ventral, and inclined anterior view of female right valve, UMMP 33763.

15–18—Neobeyrichia buchiana (Jones). *15,16*, lateral and ventral views of female left valve, with ornamentation somewhat effaced, UMMP 30516. *17,18*, lateral views of two male valves, a right and a left, UMMP 33742 and 33741.

19—Nodibeyrichia tuberculata (Klöden). Part of an inclined ventral view of a female left valve, showing ornamentation of the pouch, UMMP 32080.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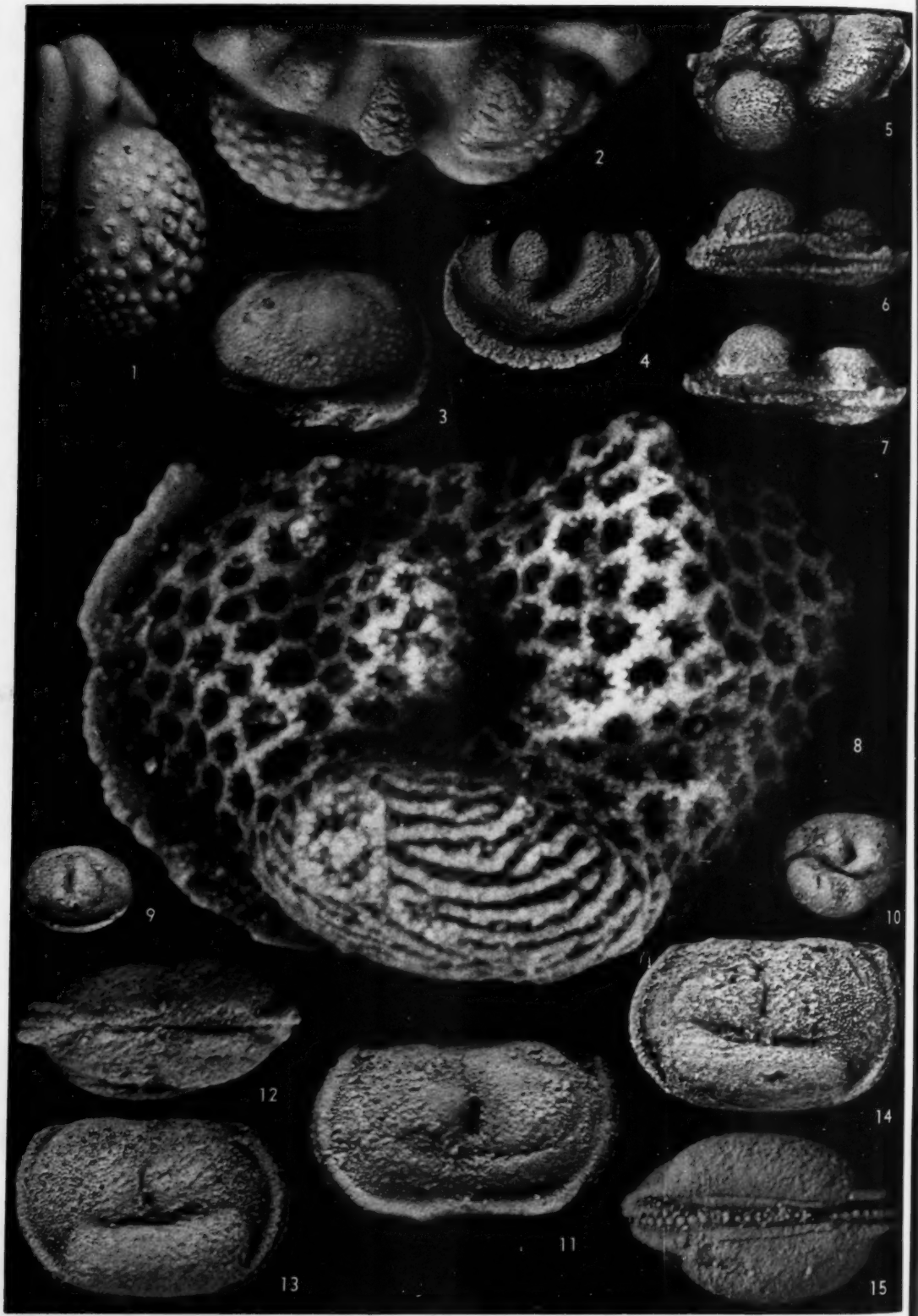
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Genus VELIBEYRICHIA Henningsmoen 1954

VELIBEYRICHIA FITTSI (Roth) 1929

Pl. 130, fig. 4–7

Lobation.—Trilobate. In the male, all lobes confluent; L1 long, curved; L2 a large node, ventrally confluent with L1 and L3; and L3 large, anteroventrally joined to L2 and L1. S1 distinct, curved; S2 broad, terminated ventrally by extension of L3. In the female, no lobes confluent; L1 an elongate node; brood pouch globular.

Extralobate area.—In the male, very narrow except below L2. In the female, both parts very narrow.

Velate structure.—In the male, a wide frill, broadly striate, distinctly in its distal part and indistinctly near the juncture with the lateral surface. In the female, continuous across brood pouch.

Ornamentation.—Lobes and lateral surface of brood pouch reticulate. Ventral part of brood pouch coarsely reticulate.

SUMMARY

Beyrichiid ostracods did not become progressively larger or smaller, but varied in size throughout their history: In Table 1 the species are arranged by size. The small *Dibolbina steusloffi* (1.24 mm. long) and the large *Nodibeyrichia tuberculata* (one adult male 3.35 mm. long) were contemporaries in northern Europe during Upper Silurian time. Great variations in length occur within one genus: adult males of *Dibolbina steusloffi* and *D. cristata* are about 1.30 and 2.10 mm. respectively, and adult females of *Neobeyrichia salteriana* and *N. buchiana* are 1.40 and 2.40 mm. respectively.

Lobation also remained variable throughout the history of the family. The unilobate *Apatobolbina* sp., the bilobate *Bolbibollia labrosa*, and the trilobate *Beyrichia kiaeri* all lived during Middle Silurian time. Similarly, the unilobate *Phlyctiscapha rockportensis*, the bilobate *Hibbardia lacrimosa*, and the trilobate *Treposella stellata* lived during Middle Devonian. We do not believe that lobation evolved in particular lineages, inasmuch as unilobate beyrichiids occur in such diverse genera as *Apatobolbina* and *Phlyctiscapha*, bilobate in *Bolbibollia*, *Bolbiprimitia*, "*Chilobolbina*," and *Hibbardia*, and trilobate in *Neobeyrichia*, *Treposella*, and *Nodibeyrichia*.

Velate structures were of many kinds in the Beyrichiidae, and did not develop any significant trends in shape. Low velate ridges occur in the Middle Silurian *Bolbibollia labrosa*, the Upper Silurian *Neobeyrichia buchiana*, and the Middle Devonian *Phlyctiscapha apleta*. Relatively thick ridges are found in the Lower Silurian *Craspedobolbina armata* and the Lower Devonian *Mesomphalus hartleyi*. Wide frills characterize the Middle Silurian "*Chilobolbina*" sp., the Upper Silurian *Dibolbina steusloffi*, the Lower Devonian *Velibeyrichia fittsi*, and the Middle Devonian *Treposella stellata*. In each group, the species are not related more closely than by family.

There does seem to be a progressive relationship of velate structure and brood pouch, however. In all female beyrichiids of the Lower Silurian, the velate structure is interrupted; in some of the Middle Silurian

EXPLANATION OF PLATE 130

All figures, except fig. *8*, ×25

FIG. *1–2*—*Nodibeyrichia tuberculata* (Klöden). Dorsal and anterior views of a female left valve, UMMP 32080.

3—*Apatobolbina granifera* Ulrich & Bassler. Lateral view of a male right valve, USNM 63699.

4–7—*Velibeyrichia fittsi* (Roth). *4*, lateral view of male left valve. *5–7*, lateral and two ventral views of female left valve (fig. *7* photographed without coating of ammonium chloride); both specimens USNM 80655.

8—*Treposella lyoni* (Ulrich). Lateral view of female left valve, enlarged to show details of surface ornamentation, UMMP 30511, approximately ×80.

9,10—*Bolbibollia labrosa* Ulrich & Bassler. Lateral views of a male and a female left valve, both specimens USNM 82406.

11–15—*Mesomphalus hartleyi* Ulrich & Bassler. *11*, lateral view of male left valve. *12–15*, dorsal, right lateral, left lateral, and ventral views of a female carapace, both specimens cotypes, USNM 53304.

females the velate structure encroaches onto the brood pouch; and in the Upper Silurian *Dibolbina steusloffi* and the Lower Devonian *Velibeyrichia fittsi* the frill is complete. We do not know whether this series in encroachment is significant or fortuitous. It is only fair to point out that the Upper Silurian *Nodibeyrichia tuberculata* has an interrupted velate structure and the Middle Devonian *Treposella lyoni* an encroaching frill. Hence, not all species conformed to the trend, if, indeed, a trend existed. For the present, we wish only to call attention to the absence of encroachment in older beyrichiids and the presence in some of the younger.

Ornamentation does not follow phylogeny or chronology. The beyrichiin *Bolbibollia* and the treposellin *Phlyctiscapha* are both smooth; the beyrichiin *Bolbiprimitia* and the treposellin *Hibbardia* are both reticulate. Even within the same genus, differences in ornamentation occur, as shown by *Neobeyrichia salteriana* with smooth lobes, *N. buchiana* with scattered pustules, and *N. maccoyiana sulcata* with reticulate lobes. During any particular epoch, ornamentation of lobes was varied. For example, of the Middle Silurian beyrichiids, *Bolbibollia labrosa* is smooth, "*Chilobolbina*" sp. is reticulate, and *Beyrichia kiaeri* is tuberculate. Of Upper Silurian species, *Dibolbina steusloffi* is smooth, *Bolbiprimitia fissurella* is coarsely reticulate. *Neobeyrichia maccoyiana sulcata* is finely reticulate, and *Nodibeyrichia tuberculata* is pustulose. Furthermore, the Middle Devonian *Phlycticapha* is smooth and *Treposella* is reticulate. We can find no tendencies for ornamentation to become more complex or simpler.

NOTES ON THE BROOD POUCH OF *Treposella*

Because *Treposella* was selected as the type genus of the subfamily Treposellinae, we wish to direct attention to the form of the brood pouch as shown in a recently discovered female specimen of *T. lyoni*, type species of the genus, from the type locality at the Falls of the Ohio. It was primarily on the nature of the brood pouch that the Treposellinae was set up as a separate subfamily in the Beyrichiidae by Henningsmoen (1954, p. 33), who presented the following diagnosis: "Beyrichiids with a mainly ventrally situated pouch. Only uni- and nonsulcate forms are known," and included the following genera: *Treposella*, *Bolbiprimitia*, *Hibbardia*, *Phlyctiscapha*, and *?Mesomphalus*. The next year, he changed the diagnosis to read (1955, p. 241): "Beyrichiidae with ventrally to posteroventrally situated pouch, in some cases almost indistinguishable on the exterior of the valve. Only uni- to nonsulcate species known. Velate structure a smooth ridge or a narrow frill. Surface smooth, pitted, or reticulate."

As can be seen in plate 127, fig. 1–3, the brood pouch in *Treposella lyoni* has a distinct semisulcus throughout its juncture with the lateral surface. The brood pouch is very similar to that in *Mesomphalus*, but differs markedly from the pouches in *Bolbiprimitia*, *Hibbardia*, and *Phlyctiscapha*, each of which has a distinct semisulcus along only the anterodorsal and anterior parts of the juncture with the lateral surface, and posteriorly is nearly confluent with the rest of the valve. Furthermore, we would emphasize that *T. lyoni* is distinctly trilobate (bisulcate), as is *T. stellata*.

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JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 1010–1018, 2 TEXT-FIGS., SEPTEMBER 1957

A *PHYSONEMUS* SPINE FROM THE PENNSYLVANIAN OF WEST VIRGINIA

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ABSTRACT—A fragmentary elasmobranch fin-spine from the Ames limestone of the Ohio Valley is referred to the *acinaciformis* species group of the organ-genus *Physonemus*. Morphology and distribution of all valid form-species are reviewed. Analogy with Paleozoic spine-bearing sharks and depositional associations of *Physonemus* spines with edestid teeth of various genera suggest the assignment of this problematical organ-genus to the Edestidae.

INTRODUCTION

THE specimen which motivated this study was collected in May of 1955 by Roger Kirkpatrick and was lent for study by Professor Neville M. Curtis, Jr., of Marietta College, Marietta, Ohio. The cooperation of both these gentlemen in investigating the find is gratefully acknowledged. My study of the stratigraphy at the source locality was supported by a grant from the National Science Foundation.

The Marietta specimen is a section of a dermal spine which (to judge from analogy) was inserted in the back of a shark-like fish and served as a cutwater for the dorsal fin. Spines of this general type, with a medullary cavity in the posterior half and with their exposed surfaces variously fluted, ribbed, or beaded, are not uncommon in marine Carboniferous beds. Unlike most such spines, which curve gently backward from the base, the present fragment has a gently concave anterior margin and must come from a spine which arched forward. This peculiarity and the beaded ornament identify it as a representative of the organ-genus *Physonemus*.

SOURCE

The spine comes from the valley of Cow creek, a northwest-flowing tributary of the Ohio river in Pleasants County, West Virginia—more specificially, from a cut on the Schultz road 0.3 mile from its junction with West Virginia Route 2 near the American Cyanamid Company plant. This place is close to the axis of the Burning Springs-Volcano anticline, a broached fold which trends north-south and bisects the Permian Dunkard basin with a band of Pennsylvanian rocks. The following section was taken at the source locality:

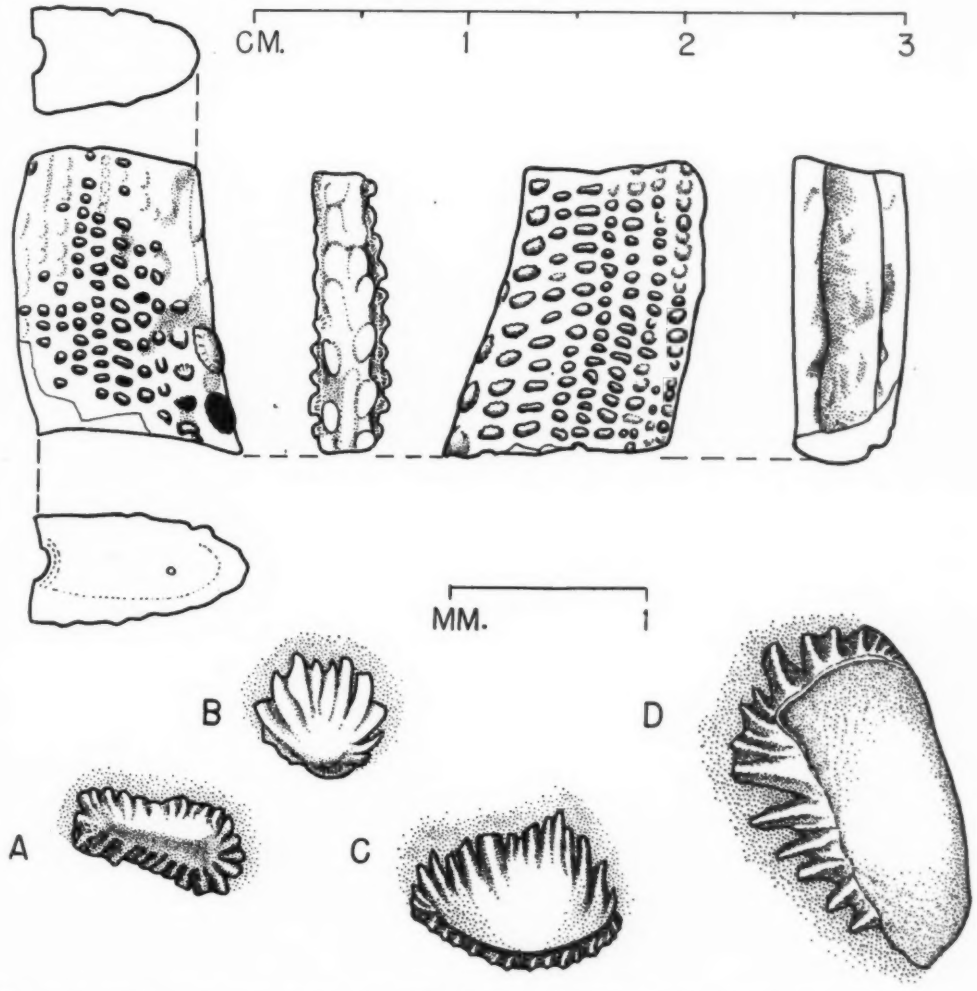
PENNSYLVANIAN SYSTEM
CONEMAUGH SERIES

	Ft.	In.
Shale, sandy, yellow	6+	
Limestone, shaly, leached yellow above, bluish below; grades laterally into hard bench; with marine fossils: *Ames*	2	1
Shale, carbonaceous/gray clay /gray shale	1	10
Sandstone, blue-gray, bedded & massive	6	1
Shale, blue-gray to gray, plant fragments in upper part	7	3
Coal, shaly: *Harlem*		5
Clay, gray, brown & red; zone of limestone nodules 3 ft. below top	8	6
Clay, chiefly red; zone of limestone nodules 4 ft. below top: *Round Knob*	9	
Clay, shaly, greenish-gray	1	
Limestone, fresh-water, rubbly layers intercalated with greenish-gray shale: *Ewing*	3	
Limestone, nodular, and greenish-gray shale, continuous with above	20±	
Sandstone, thick-bedded, with some sandy shale: *Cow Run*	20+	

According to Kirkpatrick the specimen was found lying loose as float at the bottom of a black shale bed approximately 14 ft. above road level. This bed is almost certainly the Harlem coal. Matrix adhering to the specimen, however, proves to be impure limestone. This matrix and the typical occurrence of *Physonemus* in marine limestones indicate that the actual source bed must have been the Ames limestone; its correlative age in the European classification is mid-Stephanian.

DESCRIPTION

As shown in text-fig. 1, the fragment includes only the anterior two-thirds of a short section of the spine, the walls of the medullary cavity being broken away. External surfaces are studded with vitrodentine-covered denticles aligned in longitudinal rows which are separated by shallow sulci. Ten rows are preserved on the right side, nine rows proximally and eight distally on the left. Slightly elevated scars mark the positions of denticles which have broken off. All the denticles have stellate or grooved margins. Many are subcircular in outline; others are elongated anteroposteriorly to resemble *Orodus* teeth, some as though by the fusion of adjacent denticle germs. Most have their crests or apices pointed downward (proximally). Denticles in the anterior rows show much pre-mortem abrasion: the large marginal bosses, originally globular or conical, have been worn



TEXT-FIG. *1*—*Physonemus* cf. *P. acinaciformis*. Above, Marietta College fragment as preserved. Below, A–D, enlargements of representative denticles from the right side; their counterparts are blackened in the figure above. Drawing by Patricia M. Washer.

down to the roots and retain (at most) only a collar of vitrodentine. A canal, presumably vascular, runs longitudinally through the anterior part of the spine.

In morphology the Marietta specimen is a fairly typical *Physonemus* spine without any obvious specific distinction: thus it cannot be identified without a comprehensive review of the genus. A search of the literature reveals a number of nominal form-species—many of them based on single, usually fragmentary spines—which appear to be validly assignable to *Physonemus* sensu stricto. Many specimens are embedded in hard limestones with their exposed surfaces damaged by erosion or mechanical preparation. Before useful comparisons can be made the undamaged sides of these spines must be etched free with acetic or formic acid (Toombs, 1948; Rixon, 1949; Williams, 1953)—a process which has proved conspicuously successful with specimens from the Worthen and Enniskillen collections at the Museum of Comparative Zoology.

Even with prepared material, comparisons of isolated ichthyodorulites such as these must necessarily be artificial and typological. Any meaningful zootaxonomic analysis is hampered by imperfect preservation, the lack of positively associated teeth and other skeletal parts, and our ignorance of the variation possible within a fish species or even between the anterior and posterior dorsal fin-spines of an individual fish. With these limitations in mind let us review, in ascending stratigraphic order, the species of *Physonemus* (see Table 1).

REVIEW OF *Physonemus*

The oldest recorded species is *Physonemus gigas* Newberry & Worthen (1870) from the Burlington limestone (upper Tournaisian, Lower Carboniferous). Though incompletely known, it appears to be characterized by its large size and conical, markedly stellate denticles; those in the marginal series are abruptly larger than those on the flanks of the spine.

In the overlying Keokuk limestone occurs a well-defined species, *P.* [*Drepanacanthus*] *gemmatus* (Newberry & Worthen, 1866), of which the entire spine is known (Eastman, 1917, pls. 3–4; MCZ 5752). Gentle curvature of the exposed portion, globular denticles decreasing gradually in size posteriorly, and recurved, fanglike marginal denticles near the tip of the spine distinguish this species.

American specimens of the type species, *P. arcuatus* McCoy (1848), are confined (on present evidence) to the St. Louis limestone (lower Viséan). The type horizon at Armagh, Ireland, is believed by Turner (1952) to be possibly middle Viséan in age. Typical specimens show a small, rapidly tapering, strongly curved spine with relatively small marginal denticles. Davis (1883) has described as *P. attenuatus* a spine from Armagh which, though strongly curved proximally, is almost straight for the distal half of its length. The surface pattern is unknown, but a nearly straight fragment from Armagh ("*Gnathacanthus triangularis*" Davis) which probably represents the distal part of such a spine is ornamented like *P. arcuatus*. A similar profile is seen in a spine from St. Louis[1] figured by Eastman (1917, pl. 5, fig. 1) and assigned by him to *P. arcuatus* despite its peculiarities. Until better information is available *P. attenuatus* and *G. triangularis* may reasonably be syonymized with the type species.

Tiny spine-tips from Lower Carboniferous sandstones of Victoria, Australia, which Chapman (1917) described as *P. micracanthus*, may belong to this genus but are too indeterminate to be included in Table 1. A damaged spine assigned by Chapman to *P. attenuatus* Davis is not a *Physonemus* but rather suggests *Erismacanthus* in form; preparation and restudy of this specimen are suggested.

Physonemus [*Xystracanthus*] *konincki* (Lohest, 1885) is based on an almost unworn spine from the "ampélite alunifère" (Namurian A) of Chokier, Belgium. It is readily distinguished from *P. arcuatus* by its much gentler curvature, fewer rows of lateral denticles (14 or 15), and its enlarged, toothlike anterior denticles which show a recurved-conical form almost to the base of

[1] Eastman's plate title (p. 298) erroneously places this spine (USNM 8373) and another (fig. 2, USNM 8374) in the Keokuk limestone of Keokuk, Iowa. The late Dr. W. F. Foshag kindly informed me that both specimens actually derive from the St. Louis limestone.

TABLE 1.—DISTRIBUTION OF NOMINAL SPECIES OF *Physonemus*, WITH PROBABLE SYNONYMIES

	Miss.				Penn.					Perm.			
	Kinderhook	Osage	Meramec	Chester	Morrow	Lampasas	Des Moines	Missouri	Virgil	Wolfcamp	Leonard	Guadalupe	Ochoa
P. gigas Newberry & Worthen. Burlington ls., Iowa, Ill.		×											
P. gemmatus (N. & W.) Keokuk ls., Iowa		×											
P. arcuatus McCoy													
Drepanacanthus reversus St. John & Worthen. U. St. Louis ls., Ill.			×										
P. stellatus Newberry, 1889. St. Louis ls., Ind.			×										
P. arcuatus McCoy. ?M. Viséan, Ireland			×										
P. attenuatus Davis, *Gnathacanthus triangularis* Davis. ?M. Viséan, Ire.			×										
P. koninckı (Lohest). Namurian A, Belgium				×									
P. aff. *P. gemmatus*. ?Marble Falls ls., Texas					×								
P. acinaciformis (St. John & Worthen)													
Xystracanthus acinaciformis St. J. & W. U. Carbondale fm., Ill.							×						
X. striatus Moore. U. Penn., E. Kan.								?					
Marietta specimen. Ames ls., W. Va.								×					
P. sp. indet.													
Drepanacanthus anceps N. & W. U. Mcleansboro fm., Ill.								×					
P. asper Eastman = *Xystracanthus arcuatus* Leidy. Leavenworth, Kan.									×				
P. MIRABILIS GROUP													
P. mirabilis (St. J. & W.). Carbondale fm., Ill.							×						
P. grandis (Moore). Wayland sh., Texas									×				
"*Parahelicoprion*" of Karpinsky. Artinskian, Urals											×		
P. giganteus (Waagen)													
?X. gracilis Waagen. Virgal beds, Salt Range, Pakistan												×	
X. giganteus Waagen. U. Productus ls., Salt Range, Pakistan													×
?X. major Waagen. U. Productus ls., Salt Range, Pakistan													×

the spine. Its affinities would seem to lie with *P. gemmatus*.

An imperfect spine from a dark crinoidal limestone (probably Marble Falls ls., Westphalian A) near San Saba, Texas, was figured by Eastman (1917, pl. 5, fig. 3) as a specimen of *P. gemmatus*. This spine (USNM 8108), lent for study through the kindness of D. H. Dunkle and W. F. Foshag, does indeed resemble *P. gemmatus* in its gentle curvature and its marginal denticles, which are obliquely-set, flattened ovoids proximally and enlarged cones distally. The denticles of the proximal margin, on the other hand, are precisely like those of the Marietta fragment but less abraded. So far as its preservation permits analysis, this spine appears to be intermediate between *P. gemmatus* of the Keokuk and the late Pennsylvanian specimens of *P. acinaciformis* sensu lato. We may reasonably, therefore, hypothesize a phyletic relationship between these species.

Except for the San Saba specimen, a major stratigraphic hiatus separates the Lower Carboniferous species from those of the Upper Carboniferous, the earliest of which correspond in age to the Westphalian

D of Europe. Two groups of late Carboniferous species are immediately distinguished. The first group, confined (on present evidence) to the latter half of the Pennsylvanian, comprises relatively small spines bearing fewer than 25 rows of denticles on each side; these forms are reminiscent of the Mississippian species. The second group, which ranges from mid-Pennsylvanian to latest Permian, comprises huge spines bearing about 50 rows of denticles.

The single specimen of *Physonemus* [*Xystracanthus*] *acinaciformis* (St. John & Worthen, 1875), the oldest species of the first group, was found at Carlinville, Illinois, in roof shales of coal no. 5 (Westphalian D). It is gently curved and ornamented with some 15 lateral rows of apparently smooth, rounded denticles; near the base the anterior margin bears a single row of broad, globular denticles flanked by two rows of slightly smaller ones.

Closely comparable to *P. acinaciformis* is *P.* [*Xystracanthus*] *striatus* (Moore, 1929) from an undetermined horizon in the upper Pennsylvanian of eastern Kansas. The chief difference is that the unique specimen of *P. striatus* is somewhat wider, having about 20 lateral rows, and bears two rows of proximally-inclined denticles on the anterior border. In other species (e.g. *P. mirabilis*), however, a median row of denticles may be intercalated between the marginal rows near the base of the spine. This fact, the possible effects of abrasion, and the variability to be expected in shark spines lead me to suggest that these two specimens may be conspecific.

Closest affinities of the Marietta fragment lie with *P. acinaciformis* as so defined. Its chief differences appear to lie in the tendency toward antero-posterior broadening of the lateral denticles and in the stellate ornament of their unworn bases. The latter feature, it should be noted, was not evident until the naturally weathered specimen had been further cleaned with acetic acid: similar treatment of the other specimens might eliminate the difference. A more precise identification of the Marietta specimen does not seem justified at present.

A more pronounced curvature is exhibited by two fragmentary spines from the late Pennsylvanian. The older, the type of *Drepanacanthus anceps* Newberry & Worthen (1866), comes from the basal Stephanian "horizon of coal no. 8" (St. John & Worthen, 1875, p. 460) near Springfield, Illinois. The younger, the type of *Physonemus asper* Eastman (1903), was found in a mid-Stephanian limestone near Leavenworth, Kansas. This mid-section of a spine is distinguished by its strong curvature and the form of the marginal denticles, which range from cones near the tip to laterally elongate, crescentoid weals which embrace the anterior margin of the more proximal part. Though apparently referable to *Physonemus*, these two nominal species are at present essentially indeterminate.

The larger *Physonemus* spines of the Permo-Carboniferous form a clear-cut and apparently natural group within which morphological species are doubtfully distinguishable. The earliest occurrence is that of *P.* [*Xystracanthus*] *mirabilis* (St. John & Worthen, 1875), which was found in carbonaceous shales overlying coal no. 5 in the upper Carbondale formation (Westphalian D) of Illinois. The unique specimen, which lacks both base and tip, has an antero-posterior depth of about 80 mm. at its proximal end. The lateral denticles, of which there are about 50 rows proximally, are much the same size as those in the smaller species; they increase gradually in size anteriorly. For most of its length the anterior margin bears two rows of large denticles aligned in pairs rather than alternating. Toward the proximal end these denticles broaden antero-posteriorly and finally divide into pairs of small denticles which form a double row on each side; a median fifth row is intercalated near the base.

Where comparable areas are preserved, much the same appearance is found in *Physonemus* [*Xystracanthus*] *grandis* (Moore, 1929) from the Wayland shale (late Stephanian) of Texas. This species is known only from the proximal part of a massive spine which has an antero-posterior depth of about 105 mm. near the line of insertion. Aside from size, there are no very significant differences between this species and *P. mirabilis* as known from the incomplete specimens.

While the Texas specimen is similar to

P. mirabilis it is almost identical in size and appearance with a partial spine which was found in a tunnel excavation near Krasnoufimsk, Sverdlovsk ASSR, in the Ural region of Russia. The latter specimen, which its describer Karpinsky (1925) correlated with the edestid shark *Parahelicoprion*, is Artinskian in age but may nevertheless be referred with near-certainty to the same species, *P. grandis*, as the Stephanian spine from Texas.

Physonemus [*Xystracanthus*] *giganteus* (Waagen, 1880), based on the proximal part of a spine from the very late Permian (uppermost Productus limestone) of the Salt Range near Bilot, Pakistan, approximates *P. mirabilis* in size and is thus somewhat smaller than the specimens of *P. grandis*. Morphologically it is distinguished by the persistence of two rows of ovoid marginal denticles down to the line of insertion and by a greater disparity in size between the marginal denticles and those of the adjacent lateral rows. Three *Physonemus* fragments, also from the late Permian of the Salt Range, were described by Waagen (1879) under the names *Xystracanthus gracilis* and *X. major*. These scraps probably represent *P. giganteus* but are here classed as indeterminate—which in effect they are—to protect the more adequately based but younger name *P. giganteus* from possibile reduction to synonymy.

Until additional material is available the differences between these large spines cannot be evaluated adequately. The striking similarities between them, however, strongly suggest a close zoological relationship.

ENVIRONMENT OF *Physonemus*

From earliest Mississippian to latest Permian the great majority of *Physonemus* specimens occur in unmistakably marine sediments, chiefly limestones. The three apparent exceptions, all from the coal measures of Illinois, require examination.

The sole specimen of *P. mirabilis* is stated to have come from "the carbonaceous shales overlaying coal no. 4 or 5" (St. John & Worthen, 1875). (Wanless, 1931, notes that Worthen's Fulton County "coal no. 4" is the same as his coal no. 5.) In the absence of associated fossils the environment of deposition of this shale layer is uncertain. But as Weller's classic study (1930) has shown, such "roofing shales" mark the beginning of marine transgressions over coal-swamp areas; their lithologies typically grade upward from black fissile shale to calcareous shale while their faunas concomitantly grade from brackish-water to marine associations. Exceptions to this ideal sequence of course occur, but nevertheless it is most improbable that the spine of *P. mirabilis* was deposited in a fresh-water environment.

The carbonaceous roof-shales of coal no. 5 are also the source of *P. acinaciformis*, which was found at Carlinville, Illinois, in association with *Protopirata* [*Edestus*] *heinrichsii* and *Petrodus occidentalis*. The habitat of these (or this) fish is generally interpreted as brackish water (Olson, 1946). A possible complicating factor is the presence of an undoubted fresh-water fish, the lungfish *Proceratodus carlinvillensis* Romer & Smith (1934), in a so-called carbonaceous shale at Carlinville. Only petrographic comparison of the adhering matrix can determine whether the *Proceratodus* toothplate belongs to the same horizon as the sharks: Olson (1946) has excluded it from the carbonaceous-shale fauna on the grounds that its matrix is impure coal rather than shale.

According to St. John & Worthen (1875) the fragmentary type specimen of "*Drepanacanthus*" *anceps* came from "the horizon of coal no. 8," but this phrase has no ecological significance.

We may conclude from the foregoing survey that although the *Physonemus*-bearing sharks were typically marine, one or more forms may have become adapted to brackish conditions in mid-Pennsylvanian time. Our present knowledge of these brackish-water habitats and their faunas is still fragmentary but a much more precise understanding will surely be afforded by the minutely analytical study, still in progress, of a marine transgressive sequence in black roofing shale from Mecca, Indiana (Zangerl & Richardson, 1955).

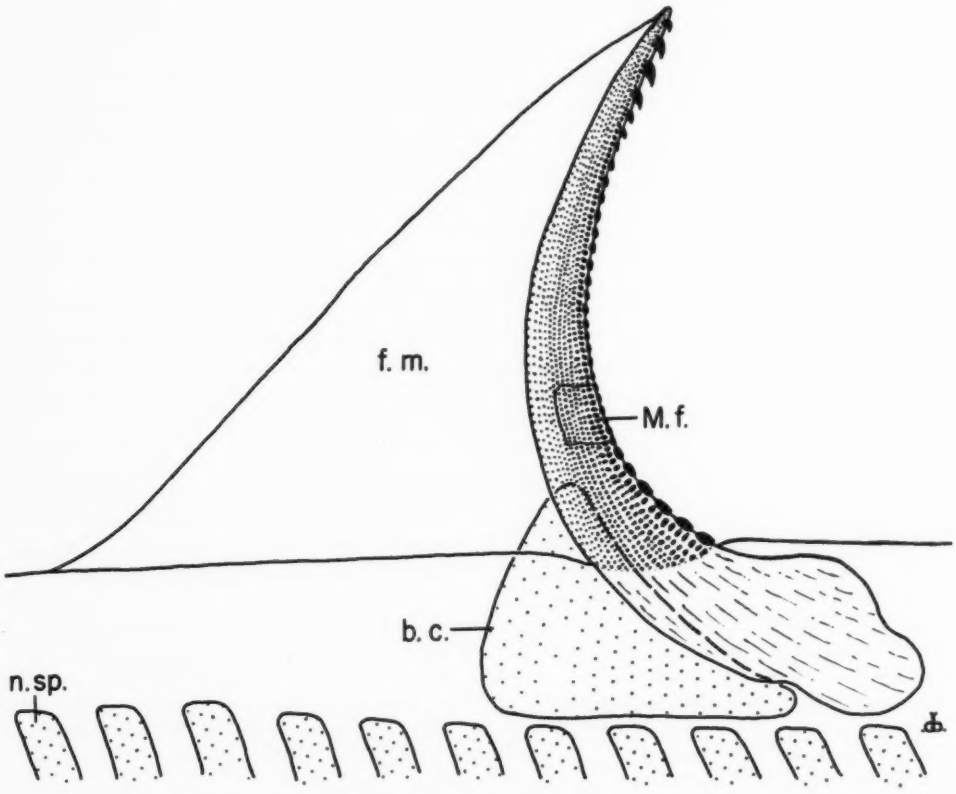
Physonemus AS A FISH

A diagrammatic restoration of the Marietta spine as it may have appeared in life is

offered in text-fig. 2. The unornamented base is inserted sagittally between the dorsal myotomes of the shark and is propped from behind by a triangular basal cartilage which rests on the neural spines of the vertebrae and fits into the medullary canal of the spine. To the smooth posterior face of the spine is attached the anterior dorsal fin. Similar arrangements are known in several genera of Carboniferous cladodont sharks (Moy-Thomas, 1936). Whether the fin was further supported by one or more radial cartilages is unknown.

We have noted that *Physonemus* spines have never yet been found in organic association with skeletal parts which might reveal the taxonomic position of this organ-genus. Differences in shape and in geological age among the form-species tabulated above suggest that half a dozen zoological genera may be represented, yet the various spines share so many features—most diagnostically their anomalous forward curvature—that a closely-knit, monophyletic group of sharks is indicated. Indirect evidence on the identity of this group must be sought in analogy with better-known spine-bearing sharks and in possible correlations of spines with teeth from the same deposits.

Its forward curvature, its flattened and lobately expanded base, and its ornament of discrete tubercles which form a knobbed and toothed cutwater clearly distinguish the *Physonemus* type of spine from homologous types found in skeletons of the primitive sharks *Ctenacanthus*, *Tristychius*, *Hybodus* and *Helodus*. The first three genera illustrate structural stages in an evolutionary



TEXT-FIG. 2—Diagrammatic restoration of the spine and associated structures, ×⅔. M.f., position of Marietta fragment; b.c., basal cartilage inserted into medullary cavity of spine; f.m., fin membrane; n.sp., neural spine.

sequence leading from the primitive cladoselachians through the ctenacanths to the dominant hybodontoids of the late Paleozoic; the fourth represents a bradyodont lineage (Moy-Thomas, 1939). The marked peculiarities of *Physonemus* suggest that it represents a type of shark more specialized than the ctenacanthids or the relatively conservative hybodontoids. Although the relationships of the bradyodont groups are most inadequtaely known, one group of specialized forms, the edestids, stand out as possible correlatives of *Physonemus*.

Such a correlation, suggested by Karpinsky in 1925 and accepted by subsequent authors (Branson, 1935; Obruchev, 1953), accords with the known associations of the spines. Recapitulating briefly, we may note that *P. giganteus* occurs in the same beds as the edestid *Helicampodus* (Branson, 1935), the Krasnoufimsk spine of *P. grandis* in association with *Parahelicoprion*, and *P. konincki* with *Campodus*.. The *Physonemus* spine from San Saba, Texas, was found in association with an edestid symphysial tooth which Eastman (1917) named *Dicrenodus texanus*. *Physonemus* spines from Pennsylvanian carbonaceous shales are contemporaries of various species of *Edestus* and *Protopirata*. I have collected edestid teeth of the *Agassizodus* type in the Ames limestone, though not at the locality from which the Marietta spine came. *Scoliorhiza*, *Edestus* and *Campodus* are possible correlatives of the Mississippian spines.

Further discussion of these speculative correlations would be unwarranted: a proper understanding can come only from finds of teeth and spines in organic association. Despite the lack of positive evidence, however, the organ-genus *Physonemus* may justifiably be rescued from the catch-all category of Ichthyodorulites and assigned provisionally to the family Edestidae.

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MANUSCRIPT RECEIVED NOVEMBER 26, 1956

REVIEW

THEOPHRASTUS ON STONES, by Earle R. Caley and John F. C. Richards. The Ohio State University, Graduate School Monographs, Contrib. in Physical Sci., No. 1, vii+238 p., December, 1956. Price $6.00.

This new translation of Theophrastus is accompanied by a revised Greek text collated from extant manuscripts and a detailed commentary which draws attention, among other things, to the mention of fossils by Theophrastus. Here is accurate information on Greek opinion concerning fossils in Aristotle's day which is of prime importance in the history of paleontology. The discussions of *lyngourion* (p. 109ff.), *pinna* (p. 134), fossil ivory (p. 135), and coral (p. 140) are of particular interest from a paleontologist's point of view but the mineralogical items are no less interesting.

Until this book was published, translations of Theophrastus in English were out of date and out of print. Professors Caley and Richards deserve our thanks for making this work available again in English and for revealing the wealth of information contained in this brief Greek treatise.

The translators were especially well fitted for their task. Professor Caley is a chemist of high professional standing and his reputation as a teacher is unexcelled. He has long been interested in the applications of chemistry to classical archaeology and has made many contributions in that field. Professor Caley has taught chemistry at Princeton and is now on the faculty of the department of chemistry at The Ohio State Uuniversity. Professor Richards is widely known as a classical scholar and has taught in that field at various universities. He is at present on the faculty of the department of classics at Columbia University.

The Graduate School of The Ohio State University is to be congratulated for sponsoring this publication and for sparing no effort to ensure good, clear printing and pleasing appearance to this volume. It is an example of fine printing as well as of scholarly achievement.

AURÈLE LA ROCQUE
Department of Geology
The Ohio State University

JOURNAL OF PALEONTOLOGY, V. 31, NO. 5, P. 1019–1028, SEPTEMBER 1957

NOTE TO AUTHORS CONCERNING FORM AND PROCEDURE FOR THE *JOURNAL OF PALEONTOLOGY*[1]

ERWIN C. STUMM AND ROBERT V. KESLING
Museum of Paleontology, University of Michigan, Ann Arbor

ABSTRACT—Only articles on paleontology should be submitted to the *Journal of Paleontology*. These may include faunal descriptions, revisions of taxa, and discussions of morphology, but papers dealing primarily with stratigraphy and structure should be turned in to other publications.

Articles are easier to read when the material is arranged in the general form used in other articles of the *Journal*. Within this framework, freedom of expression is permissible and desirable. Editorial revisions are limited to incorrect form, faulty grammar, vague, ambiguous passages, and irrelevant matter. After suggested revisions have been penciled into the manuscript, it is returned to the author for his inspection. He may correspond with the editors about any changes. Both editors and author want the finished product to be clear, intelligible, and concise.

SUBJECT

ONLY a few manuscripts are rejected because of their subject. If they contain nothing about paleontology there is no problem. The boundary between stratigraphic paleontology and paleontologic stratigraphy, however, is difficult to determine. Some authors combine into one article detailed faunal descriptions and lengthy accounts of geologic structure and measured sections. They present information that properly belongs in two papers. Their manuscript must be drastically pruned to be suitable for the *Journal*.

Certain articles are justifiably longer than others. Monographs, of course, cannot be handled by the *Journal of Paleontology*. Brief papers are placed in Paleontological Notes, but the distinction between article and note is somewhat tenuous; publication in the Notes is not meant to be disparaging. Placement of a paper is on the basis of its brevity, and the layout of the number, not its importance.

Nothing, NOTHING warrants a vitriolic attack on a colleague. No matter how cleverly written, no matter how scientifically sound the refutation of his deductions, the scathing denouncement of a person is not fit for this *Journal*. Most diatribe of this kind is submitted as "Comments on . . . ," "Review of . . . ," or "Some remarks about . . . ." Worse still, the taunted one may be equally nasty in his "Reply to . . . ." Please, gentlemen! Even crusty old editors can be revolted. If you simply can't desist from venting your hatred of other workers, at least don't send it in to be published. It won't be. Scientists make mistakes from time to time. If you disagree with someone's classification, write up your reasons for suggested changes. If his "new species" turn out to be homonyms, why not drop him a letter? He will appreciate your courtesy.

Scientific papers we do not censor, believing it unfair both to screen the reader from the subject and to screen the author from his public.

RESPONSIBILITIES OF AUTHOR AND EDITOR

In his delightful little book, *Recurrent Maladies in Scholarly Writing*, Dr. Eugene S. McCartney says of the many manuscripts he has edited, "Some were in superb shape, the majority were in fair shape, others were in poor shape, and an occasional one had no shape whatever."

We have been informed, but not yet admonished, that the content of each article is the responsibility of its author. This raises several questions. Is the content of the manuscript inexorably the verbatim content of the article? To what degree is the responsibility shared? Should the *Journal* be a collection of "authors' responsibilities"?

In our brief experience, contributors may

[1] For contributors to the Paleontological Society numbers.

be classified in two taxa. Some feel that editors serve as accumulators and periodic transmitters of manuscripts to the printer, and should never be so presumptuous as to alter a word of the immaculate composition. This touch-it-at-your-peril school of authors is opposed by the editor-knows-how-to school, whose adherents supply brief notes and hopefully trust that editors will write an article on the subject for them. Editors are supposed to placate one group, satisfy the other, and produce a publication of certain standards and congruity. The course between prerogative and duty is not an easy one.

The author has certain obligations that cannot be by-passed. In writing your article, analyze the point at issue; organize your discussion into logical topics; and harmonize with the style of the *Journal*. Read the manuscript carefully. If the typist left out a paragraph here or a page there, find it out before sending in the paper. In particular, check the accuracy of measurements, numbers of catalogued specimens, enlargements in illustrations, and references. The editors do not send for specimens to confirm their size or shape, and seldom check on quotations. Unless there are obvious discrepancies between the text and the explanation of plates, or between text and references, the errors will probably be published. We hesitate to mention the matter to paleontologists, but manuscripts are still coming in with scientific names misspelled. A few (but only a few) of these errors we recognize and correct.

What you say must be as clear to the reader as to you. Cut away all that is extraneous. Present your best, retyped if necessary.

On the whole, we are parsimonious with the blue pencil. If a manuscript should be rewritten to a great degree, it is returned immediately for revision. Inconsistent descriptions and dissociated paragraphs are questioned. Although our editing is admittedly incomplete, we feel obliged to correct mistakes in grammar and misspelled words. When a boner reaches publication, the editors share the albatross with the author. Hence, it seems only fair that they be permitted such pedantic foibles as un-dangling participles. Photographs which do not show details clearly or which contribute nothing to the article must be rejected. Crudely lettered charts are also anathema. In any case, manuscripts will be returned to the author, or a long detailed letter will be written to him, so that he may study the suggestions. If he has good reason to defend his expressions, we can work things out by correspondence. Our additions or deletions are not dictates, and we humbly ask indulgence if we have misinterpreted.

PREPARATION OF MANUSCRIPT

We have not yet capitulated to the newfangled term "typescript," but that is what we are talking about. Type all parts of the manuscript, except diacritical marks, Greek letters, and mathematical symbols which your typewriter may lack; add them in ink.

Use only good quality white bond paper in 8½ by 11 inch sheets, not colored, not highly glazed, not fancy textured, not thin and flimsy, just good standard typewriter paper. It will be handled by editors, printers, and proofreaders. It should be strong enough to withstand erasures. The typewriter ribbon should yield a good black impression.

Leave margins of about 1½ inches on all sides of the page. Double space all, yes all, of the manuscript. If there is a brief addition (a word or two) to the typed copy, you may write it in ink. Do not paste up over-length pages. If there are major revisions, retype and add new pages; should an insert end in the middle of a page, draw a diagonal blue line (known to printers as a "run on") from the last typed line to the bottom of the page. Number the pages of the final draft. Copy for explanations of plates and text-figures comes at the end. The *Journal* uses running heads in capital italics, with the author's name on the left-hand, even-numbered (technically, the "verso") pages and an abbreviated form of the title on the right-hand, odd-numbered ("recto") pages. If you wish to compose your own recto running head, type it on a separate page, label it "Running head," and send it with the manuscript. It must be short, only about 35 letters at most, and still tell the taxonomic and stratigraphic highlights of the article; it is essentially an abstract of the title.

Send us only the original. Although we

have not heard of manuscripts being lost in the mail or express, keep a carbon copy as insurance. If we have only a few questions, it will not be necessary to send the manuscript back to you; we can explain proposed changes with page references.

PARTS OF THE ARTICLE

Top line.—As the first line of the manuscript, about one-third of the length from the top of the first page, type in capital letters: JOURNAL OF PALEONTOLOGY, V. 00, NO. 0, P. 000–000, PLS. 00–00, 0 TEXT-FIG., . . . If there are text-figures, enter the number; if not, omit the last entry. The end of the line will be filled in later with the month and year of publication, and the 0's will be replaced with the proper numbers.

Title.—Type in capital letters and center on the page below the top line. Underline generic and specific names if they are used. Be brief, but include geologic age and taxonomic position if they are important. If the fauna is from a limited geographic area, so state. This information helps the general reader, and most of us are general readers. Use verbs only if absolutely necessary to emphasize the subject matter.

Author.—Type in capitals and center. Omit "By" before the name.

Address.—Give institution or company name, and, if not implied in the preceding, the state. Omit "The" where it occurs as the first word in the name of the organization. If there is no institutional or business affiliation, give street, city, and state.

Abstract.—Except for short notices, in which the title serves as an abstract, an abstract is mandatory. Precede and follow it by short centered lines. Begin with ABSTRACT in capitals, not indented, followed by a dash. The abstract is the essence of the paper, the new discoveries, the importance of your interpretation, or the reasons for your conclusions. It should convey specific information, not vague generalities. Do not resort to "telegraphese." Be straightforward; avoid elegancies. Landes (1951, p. 1660) has an excellent discussion of the abstract. New taxonomic names proposed in the paper should appear in the abstract.

Table of contents.—This is required only for very long articles.

Headings.—Headings are provided for the convenience of the reader. Keep them short, informative, and in logical sequence. Two types of headings are enough to divide the subject matter of most articles.

CENTER HEADINGS

are typed above major divisions, centered, in capitals. Underline each center heading with two blue lines (indicating it is to be set in small capitals). Material under one center heading may be subdivided by

Side headings.—which are indented for paragraphing, underlined once for italics, and followed by a period and dash. Except for proper names, only the first word in a side heading is capitalized. If a name of a genus or species is part of a side heading it is not italicized.

If further subdivisions are called for, centered headings in italics (underlined once) and in roman type (not underlined) should suffice.

Systematic descriptions.—The majority of papers in the *Journal* contain a section on descriptions of fossils. Start this section with SYSTEMATIC DESCRIPTIONS as a center heading. Below this, also centered, list a taxon of such rank that the average reader will recognize it. For example, he should know immediately that you are going to describe trilobites and not gastropods. Capitalize only the first letter of the taxon, but all letters in the name of the taxon, as in Class GASTROPODA, Order NEOTREMATA, or Genus SULCELLA. In successive centered headings list taxa of lower rank. Families, genera, and species should be followed by their authors; original dates of publication are optional. New families, genera, and species are followed by a comma and "n. fam.," "n. gen.," and "n. sp." respectively. To insert your name after new taxa seems an affectation.

For genera, it is desirable to name the type species and state how it was designated.

If a species is illustrated, reference to plates and figures or text-figures is centered below the name of the species, such as Pl. 2, figs. 4–6; Text-fig. 3.

Synonymy has been discussed previously (Stumm & Kesling, 1957, p. 671). Each specific name is entered only once and is fol-

lowed by references to all articles in which it has been published.

Most descriptions of new species are separated into parts with side headings, such as *Diagnosis*, *Description*, *Remarks*, *Occurrence*, and *Types*. The *Description* may be written in complete sentences or in "telegraphese," by which verbs are omitted. It is very important to describe morphologic features of all species in the same order. Whatever terminology you adopt, use it consistently.

Remarks should include comparison of the new species with closely related species, observations on unusual preservation, discussion of unusual structures, comments on burial attitudes, and any other pertinent information about the fossils which does not belong in *Description*. Optionally, the derivation of the name may be given.

Occurrence states the geographic locality, the stratigraphic layer, the abundance of specimens, and, if not given elsewhere, the collector. Under *Types* list the catalogue numbers and repository for type specimens. A brief identification of the material is helpful, such as "left clavicle," "right valve," or "carapace with thoracic appendages."

Footnotes.—Most footnotes are uncalled for.[1] They should never be used for references. Parenthetical remarks can almost always be phrased to fit into the text. This leaves but one good reason for footnotes: to explain in full long headings for which there is not enough space in tables. If you persist in using them otherwise, please refer to our previous condemnation (Stumm & Kesling, 1957, p. 666) for form.

References.—Detailed rules and examples are found in Stumm & Kesling, 1957, p. 671. Use references to pinpoint the sources of your information. Check quotations carefully, avoid lifting selections from context to suit your purpose, and paraphrase long passages. Quotations longer than three lines will be set in smaller type; it works out best for the author to use quotation marks regardless of the length of quotations in his manuscript.

Literature cited or *Bibliography.*—Be sure that all references have a citation in the LITERATURE CITED. Observe the correct form and abbreviations (see Stumm & Kesling, 1957, p. 666–672).

Explanation of plates and text-figures.—Never paste the explanation to the plate or text-figure. The explanation must go to the printer and the plate or text-figure to the engraver. There is one format for explanation of plate and another for text-figure.

Type each plate explanation on a separate page. Begin with a center heading EXPLANATION OF PLATE 1 in capitals. The proper number will not be known until the issue is laid out, at which time we substitute it for your number. At the left margin write FIG. in capitals, followed by the number *1* (underlined for italics) and a dash. Enter the species name only once for each plate, and include all figures of specimens of the species in the preceding numbers. For each succeeding species, do not repeat "FIG." at the beginning; instead, align the number or numbers under "*1*" at the left. Tell what each figure shows, identify the particular specimen by catalogue number, and indicate the magnification (unless a scale is drawn on the plate). If all figures on the plate are magnified equally, a line can be entered below the center heading, such as "All figures are ×10." By convention, if specimens of the same species are illustrated in two successive figures we separate the corresponding numbers by a comma, as "*9,10*"; if in more than two successive figures we use a hyphen, as "*11–14*;" and if in non-successive figures we use a comma, as "*15,19,23.*" A sample explanation of plate is given below.

Because text-figures may be of subjects other than fossil specimens, the form of the explanation may vary. Each explanation is typed on a separate page. Each begins at the left margin with TEXT-FIG. in capitals, followed by the number (underlined for italics) and a dash. Enter the scientific name first if a specimen is illustrated. Subsequent lines are indented. Make the explanation direct and informative.

WHAT YOU MEAN

Uninterrupted text copy is called "straight matter" by publishers and printers; prospective authors might be encouraged to make matters straight in the straight matter. To call attention to all kinds of er-

[1] They are also so expensive that it is with great reluctance we offer this example. See how they interrupt the reader? Inept, too. All this could have been said in the text.

rors which have confronted us would use up several pages, so we will inveigh against the persistent grammatical mysteries.

1. The Case of the Ambiguous Antecedent. "It" is a chronic offender, but there are other criminals. Can you solve the following?

> The shell has a rough texture, but it is possible that part of it is adhering matrix.
>
> The right valve bears a long spine. Near its posterior end it is composed of clear calcite.
>
> The dorsal lobe is separated by a shallow groove from the ventral lobe. This part of the shell is extremely thin.
>
> One of the remarkable features of the immature shell is the spinose ornamentation. They are long, hollow, and fragile.

2. The Case of the Pendant Participle. No other suffix sets us a-sleuthing as quickly as *-ing*.

> Knowing the ontogenetic series, meraspis stages can be readily separated from the others.
>
> Removing the matrix carefully, all of the plates lay in close association.
>
> One specimen was found with a few appendages preserved and showing the eyestalks.
>
> Being dicyclic, the classification of this crinoid. . . .
>
> Varying from .72 to .78 mm., the average length is found to be .74 mm.

3. The Case of the Most Complete Comparative. Certain adjectives are uncomparable; they cannot be used with the words *more* or *most* or with the terminations *-er* or *-est*. Some of these adjectives appearing in manuscripts are: absolute, basic, complete, contemporary, devoid, empty, entire, essential, final, full, ideal, impossible, obvious, perfect, possible, pure, sufficient, superior, and unique. The use of comparative with these words involves "nearly," "almost," or "not quite." One can say of a specimen that it is more nearly complete than another, but not that it is more complete. It is also "absolutely essential" and "utterly basic" to "more completely" observe the corresponding nouns and adverbs, which in their "fullest entirety" are "very impossible" to compare.

4. The Case of the Incredible Impossibility. Some statements just don't make sense. Most of these explode immediately, but some have a long fuse, such as the topic sentence that says the specimen has three lobes and the rest of the paragraph that describes four lobes. The following are over with quickly:

> The holotype is one of four other specimens collected by . . .
>
> Immature specimens have been found in the empty carapaces of the adult.
>
> The ends of the spines are 2 mm. long.
>
> The average length is about 25 mm., but it varies greatly.

5. The Case of the Fallible Fact. A fact is true, definitely, undeniably. It has no probability or question, and it does not need to be confirmed. Do not use "fact" when you mean "statement," "assumption," "probability," or "indication." The sentence is improved if the parenthetical "in fact" is replaced by "in brief": "The glabella, the palpebral lobes, the free cheeks, the genal spines—in fact, all features of the cephalon —are like those in the paratype."

6. The Case of the Effeminate Affectation. Occasionally, we receive fossil descriptions in which morphologic structures are referred to by such elegancies as "exquisite," "beautiful," "graceful," and "lovely." Festoon not your writing with such bespangled garlands, sentimental though ye be. Size,

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EXPLANATION OF PLATE 2

FIG. *1—Hollinella sella* Stover. Right lateral view of male carapace, NYSM 10818, ×20.

2–5—Hollinella epakra Stover, *2,3*, lateral and ventral views of male right valve, NYSM 10822; *4,5*, lateral and ventral views of female right valve, the holotype, NYSM 10823, ×25.

6–11—Subligaculum aculeatum, n. sp. Right lateral and dorsal views of one male and two female carapaces, USNM 41308, 41316, 41447, ×30.

12–15—Ctenoloculina cicatricosa (Warthin). *12–14*, left lateral, dorsal, and ventral views of female carapace, NYSM 10917, ×25; *15*, interior view of female left valve converted to calcium fluorite and viewed by transmitted light, showing muscle scars in the region of S1 and S2, USNM 42657, ×100.

shape, position, and relation are enough, thank you.

7. The Case of the Unparalleled Parallel. Descriptions are enhanced by the use of parallel constructions to compare morphologic features of the same magnitude. Awkward sentences result when features are not of the same magnitude or when they are not compared in parallel constructions. Witness the following:

> In the pedicle valve, the hinge is formed by long teeth but by deep sockets in the branchial. (The hinge is formed by long teeth in the pedicle valve and deep sockets in the brachial.)

> On the dorsal side the carapace is convex and tuberculate, but flat and smooth on its ventral side. (The dorsal side of the carapace is convex and tuberculate, but the ventral is flat and smooth.)

> The eye facets are well developed, but the pygidium is twice as long as broad.

There are other malefactors, not all of which are apprehended by the editors. They involve wordiness, illogicality, and pompous style.

> The formation exposed here is not certainly identified but may possibly be part of the Exwyzee formation. (The rocks exposed here are. . . .) For one formation to be part of another is absurd.

> One may well be censured for defining a species on material which would seem so nearly inadequate as in this case—*21 words.* (Some workers consider such incomplete specimens inadequate to establish a new species—*12 words; or* These specimens may seem too fragmentary to warrant a new species—*11 words.*)

The following gave us some anxiety until we reached the end of the sentence and reviewed it, "A wide frill commonly found in kirkbyid ostracods running from one end to the other is not present in this species."

An up-to-date dictionary and Roget's *Thesaurus* are indispensable in writing. The following books and articles offer helpful suggestions on grammar and composition.

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ILLUSTRATIONS

It has been said that one picture is worth a thousand words. By corollary, a bad picture is valued at a thousand bad words, and a useless picture at a thousand useless words. Illustrations are such integral parts of the paleontologic article that each author should strive for the best he can achieve. It is disconcerting to read an elaborate description of a morphologic structure with reference to a figure, and discover that the figure does not show it at all.

All originals must be submitted clean and mounted on stiff cardboard or illustration board. Figures should be attached to plates firmly.

By whatever means they are made, figures of specimens should appear as though lighted from the upper left. Very few problems of configuration warrant breaking this rule. Nearly all specimens can be lighted conventionally and satisfactorily by shifting the highlight and the auxiliary lights and by varying their intensities. If your specimen is lighted in a different way, elucidate in the

EXPLANATION OF PLATE opposite.

Personally, we dislike retouching, particularly that which is obvious or which produced an incorrect outline and shape in the picture of the specimen. Why use a camera at all if the photograph is to be buried under paint, carbon, and graphite? At least, admit that your illustration is retouched.

Combining figures on a plate is an art. One can spend hours composing a single plate. Plates are more attractive if the larger figures are at the bottom. Tiny figures widely spaced are repellent. Be miserly with the background. If only one plate is needed, enlarge the figures to fit it. Do not submit four plates with only figures enough for two. White or black background is the choice of the author; gray is wrong. The printing process imparts certain advantages to the white background, since white is an absence of any priting. The plate for printing is blocked out from desired areas and nothing is printed there. For black background, the original must be solid black. Even the trimmed edges of figures and numbers must be coated with duil black. Re-engraving to change dark gray to black is too expensive for our budget. Semimatte photographic paper exposed, developed, fixed, and washed produces a satisfactory black background.

Numbers for figures should never be so large they detract from the appearance of the plate. On the other hand, they should be legible (after reduction). We have a few sets of "ready mades" printed on gummed paper, which we will supply until they are used up.

Illustrations are of three kinds, according to the method used in their reproduction: zinc cuts, halftones, and collotypes. Each has certain standards for the original copy.

Zinc cuts.—Copy for zinc cuts must be black and white. Shades of gray are impossible to reproduce. Large black areas do not print cleanly.

Zinc cuts are reproduced in two widths: single column 2½ inches wide, and double column 5¼ inches wide; maximum height for either is 7½ inches. Plan your original copy to reproduce at one or the other width.

Use good drafting paper or illustration board; soft, unfinished cardboard is a poor economy. Consider from the start of the drawing what you expect in the final printing. Bear in mind that when the original is reduced, lettering will be smaller, lines narrower, dots more closely spaced, and faint dots may not survive. Outlines should be of continuous width, never blurred. The shape of the specimen may be indicated by line shading, stippling, or discrete use of thin adhesive overlay paper on which a pattern of dots is printed. Without using trade names, we strongly recommend overlay paper without gloss. A shiny surface reflects light so that the pattern of dots does not come through clearly in all parts of the zinc cut.

Pages larger than the standard size must be folded and tipped-in, expensive processes. Try to fit your material onto two standard pages instead of one oversized chart.

All lettering on charts should be neat, aligned with the border, and large enough to be read easily. Typewritten labels will be rejected. Very few people are sufficiently skilled to do acceptable lettering by hand; a mechanical lettering set assists greatly in making clear labels and titles. "Good lettering will not strongly attract attention, but even slight imperfections of form, spacing, slant, and shading will be quickly detected and criticized" (Ridgway, 1920, p. 54).

In labeled diagrams and drawings, abbreviate only when essential because of space limitation. Long glossaries of abbreviations hamper the reader. He may also be annoyed to find that "n. sp." means, for your particular drawing, "neural spine."

Halftones.—From time to time illustrations are submitted that fill only half a page. They cannot be reproduced as collotype, which turns out a full page (5¾ by 8¼ inches) at a time, unless the author wishes to wait for publication until another article is sent in with a small illustration that will exactly fill up the unused part of the plate. Nearly all half-page illustrations are printed as halftones, if they are continuous tone (black, white, and shades of gray).

Originals for halftone may be photographs or drawings made with carbon pencil, graphite pencil, brush, or air brush. The original should have slightly more contrast than that desired in the final reproduction. Beware of very light gray against a white background or very dark gray against black, because the outline of the specimen may be lost.

Collotypes.—Collotype reproduction is

used for most plates. The maximum size of a plate is $5\frac{3}{4}$ by $8\frac{1}{4}$ inches. Large plates should be designed to reduce to these dimensions. No plate should be smaller than 5 by 7 inches.

The same kinds of originals can be used for collotype as for halftone, but they should have less contrast than that desired in the finished plate. The best copy for collotypes has neither black shadows nor white highlights, but shades of gray for both. This does not mean that photographs can be out-of-focus; the photographic negative must be sharp and crisp, but printed on paper of low contrast. By trial we found that negatives which give the desired contrast on "3" paper will yield best results when printed on "2" paper. All figures on a plate should have the same degree of contrast.

If you have any doubt about how well your plate will reproduce, we will ask the engraver to give us a decision.

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Authors will receive galley proof of their papers 5 to 9 weeks in advance of the date of publication. In case of authors with foreign addresses proof will be sent by air mail. It is absolutely necessary that the galley proof be corrected and returned within 24 hours of its receipt at the address furnished by the author. If the author is out of town or in the field it is his responsibility to designate someone to correct and return proof within the 24-hour limit. Failure to do this will make it impossible to include the author's corrections in the final version.

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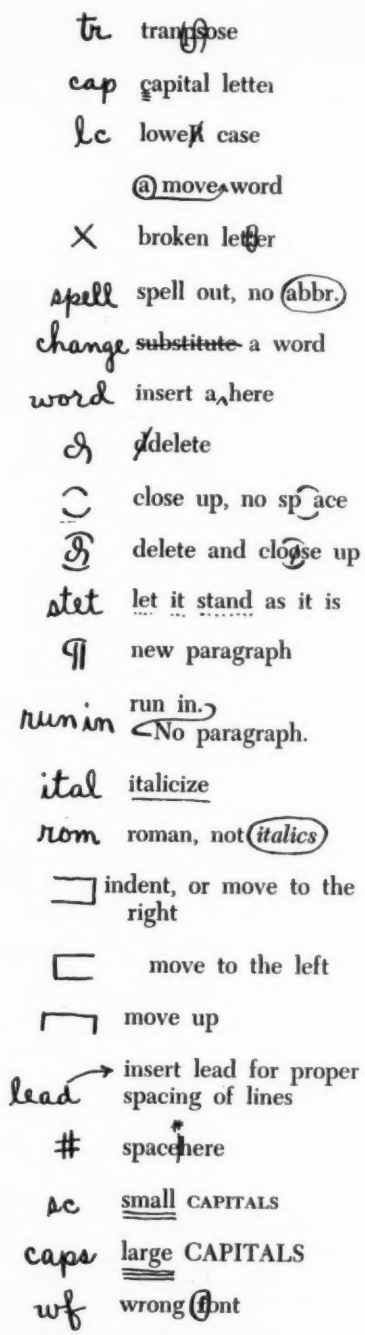

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tions, the manuscript, and the originals of all illustrations.

Proof and manuscript should be sent first class mail, special delivery. It is not necessary to register them but this may be done if the author desires.

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Almost every writer finds the task of editing his own work difficult. It is natural for him to read into his own writing what he intended to say rather than what he actually said. The technique in learning to write clearly is learning to rewrite. Rewrite anything, anything that isn't clear.

A/tr/original/tr rewrite

ital

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ENVOY

There are probably some points on publication which we have overlooked. If you have questions, write to the editor.

We trust that this article, like its predecessor (Warthin & Weller, 1951), will help authors to establish a desirable degree of uniformity in the *Journal.*

Paleontology needs good writing. You will want to do your part. You are most convincing when you use sound reasoning and good sentences in your writing and substantiate your claims with clear illustrations. Write to be understood.

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CORRECTION

The note by R.E.H. Reid entitled "On Hexactinellida, "Hyalospongea," and the classification of siliceous sponges" in the January issue of this *Journal* (Vol. 31, No. 1, 1957, p. 282–286) contains the following error: p. 285, col. 2, line 24 (diagnosis of Class Silicea Bowerbank, last line): for " . . . or of spongin only, or with no spicules." read " . . . or of spongin only, or with no skeleton."

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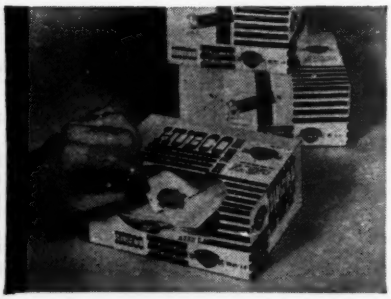

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NOTICES

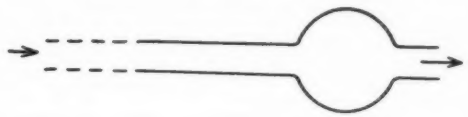
IMPROVED METHOD FOR WHITENING FOSSILS FOR STUDY

CHR. POULSEN
Mineralogical Museum., Copenhagen, Denmark

It is well known that surface outlines and markings are brought out in great clearness and perfection by whitening fossils with a film of ammonium chloride. However, good results depend on the amount of atmospheric humidity, too much humidity resulting in uneven deposition of the film. Moreover, a film of ammonium chloride tends to become grainy, the grains frequently being clearly visible at magnification ×6.

The writer has experimented with other sublimates in order to avoid grainy coatings. The best results were obtained in the following way:

Small pieces of pure antimony are heated in a spherical chamber formed by enlargement of part of a quartz tube (text-fig. 1). When the antimony has been sufficiently heated (the quartz chamber must be glowing), an air current is blown through the quartz tube in the direction indicated in the figure in order to expel the white smoke of tetra-oxide of antimony formed in the chamber. This sublimate can be deposited upon



the object as a uniform, thin film, varying according to its thickness from light blue to ivory white, and can be viewed under the microscope at magnification ×200 without exhibiting any grainy structure. The deposition of this sublimate is not in any perceptible degree dependent on the amount of atmospheric humidity.

NOTICE CONCERNING *ACTA PALAEONTOLOGICA POLONICA*

Attention of North American paleontologists is called to a new Polish journal which made its appearance in 1956—*Acta Palaeontologica Polonica*, published in Warsaw with the distinguished Polish paleontologist Prof. dr Roman Kozłowski as Editor-in-Chief. Volume 1, which consists of four numbers and totals 394 pages in addition to plates and plate captions, contains the following articles:

Sur *Rhabdopleura* du Danien de Pologne, (R. Kozłowski); Foraminifers from the Middle Devonian of the Holy Cross Mountains, (S. Duszynska); *Polyzygia* Gürich, an Ostracod genus from the Givetian of the Holy Cross Mountains, (F. Adamczak); Observations sur la morphologie de *Pygomalus analis* (Agassiz), (Résumé; complete article in Polish), (W. Jesionek); Miliolidea tortoniens et sarmatiques de Suchowola, (Résumé; complete article in Polish), (A. Sulimski): On the parasphenoid of the Brachythoraci, (J. Kulczycki); Sur l'évolution de *Lagena sulcatiformis* n. sp. dans le Crétacé supérieur en Pologne, (Résumé; complete article in Russian), (K. Pozaryska and A. Urbanek); Lizards from the Pliocene of Poland, (M. Młynarski); On a new species o Emydid-tortoise from the Pliocene of Poland, (M. Młynarski); Sur quelques appareils masticateurs des Annélides Polychètes ordoviciens, (R. Kozłowski); *Amphipora* dans le Dévonien de Pologne, (Résumé; complete article in Polish), (W. Gogolczyk); Evolutionary rate of craniometric traits in Hominidae, (A. Wiercinski); Nouvelles observations sur les Corynoididae (Graptolithina), (R. Kozłowski); Pachyphyllinae from the Middle Devonian of the Holy Cross Mountains, Part I, (M. Rozkowska); Insectivores, Bats and Rodents from the early Pleistocene bone breccia of Podlesice near Kroczyce (Poland), (K. Kowalski).

One noteworthy feature of the journal is the fact that each article appears in at least three languages; the complete article, in the first four numbers, may be in English, French, Polish or Russian, and in each case there are résumés in two additional languages, which may be Polish, French or Russian.

Professor Kozłowski and his associates are to be strongly commended for starting this

new *Acta*, and paleontologists everywhere will wish them success in their venture. The spirit in which the journal was started is best expressed in Professor Kozłowski's own words (personal communication):

> "Pour modeste que soit encore notre publication, je pense que l'ayant initiée avec mes elèves nous allons contribuer au développement de la paléontologie."

Correspondence may be directed to: Prof Roman Kozłowski, Zakład Paleozoologii U. W., Nowy Swiat 67, Warszawa (Warsaw), Poland.

22 January 1957

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CONCENTRATION OF OSTRACODES BY ALCOHOL FLOTATION

LOUIS S. KORNICKER
Columbia University

Articulated ostracodes from Recent, Pleistocene, and some Tertiary sediments contain hollow cavities which permit these forms to float in liquids; whereas, denser materials in the sediment sink. This property of ostracodes permits their easy concentration; sediment is poured into a liquid which is then put through a loosely woven fabric such as a paper hand-towel which retains the ostracodes.

It is common practice to use high specific gravity liquids such as carbon tetrachloride for the separating medium. If the balance of the sediment consists of dense calcite or quartz, these liquids are very satisfactory; however, if the sediment contains a considerable portion of other organisms such as calcareous algae, forams, small snails, etc. these will be concentrated along with the desired components. In addition, fine carbonate tends to float on the heavy liquid.

The writer tried the carbon tetrachloride method on sediment samples obtained from the Bahamas and found that the concentrate was diluted to such an extent by Peneroplids and the calcareous alga, *Halimeda*, and other organisms, that it was not practical to use this method on these sediments. Alcohol, on the other hand, which has a low specific gravity, when substituted for carbon tetrachloride resulted in a float consisting of almost a pure concentrate of articulated ostracodes and smaller foraminifera. Peneroplids and *Halimeda* which float in carbon tetrachloride sink in alcohol.

When alcohol is used as the flotation medium only 40–50% of the articulated ostracodes and practically none of the separated valves are removed from the sediment; however, the articulated ostracode content of the float is 5–16 times more concentrated than that obtained when using carbon tetrachloride. Comparative results from three typical samples are presented below:

NUMBER OF ARTICULATED OSTRACODES IN 0.025 GRAM

Original untreated sample	Carbon tetrachloride float	Alcohol float
<1	11	178
3	30	150
<1	2	33

THE FOLLOWING OFFICERS WERE ELECTED AT THE APRIL 19 MEETING OF THE PACIFIC COAST SECTION OF THE PALEONTOLOGICAL SOCIETY

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